Nuclear regulator Nunzio Palladino streamlines rules to improve safety
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Chemical & Engineering NEWS

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Adhesives change old-time glue into growing chemical specialties

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FEW COMPANIES ESCAPE EARNINGS PLUNGE

There is little joy in the U.S. chemical industry at the end of the third quarter. With 30 major U.S. chemical companies reporting so far, it's safe to say the third quarter simply continued the industry's steep earnings slide, which began in fourth-quarter 1981.

Of these 30 companies, 27 have posted declines in earnings, two with red ink. Just as serious, sales for 23 of them also dropped, an unusual event in the chemical industry. Sales decreases ranged from 1 to 20% or more from the same period last year.

Since chemical industry sales this year already were down almost 7% through the first six months from last year, it's certain that sales will be down for the full year. In recent decades, this has happened only once before, in 1975, for basic chemical companies.

Sales and earnings declines for chemical companies run across the product board. Plastics operations still are down, although at a few companies—notably Monsanto and Allied—plastics performed better in the third quarter this year than a year earlier. Fibers also are off from a year ago; fertilizers are not performing well; and even specialty chemicals such as adhesives and synthetic lubricants now are getting hit. (One of the few exceptions is specialty adhesives; see page 8.)

In fact, many of the harder hit companies in the third quarter were smaller, more specialty-oriented firms. For instance, earnings at adhesives maker H. B. Fuller dropped 34% from last year's third quarter to $2.5 million. Sales were off 5% to $79.6 million. Another adhesives

Sales, earnings for almost all companies dropped in third quarter

	Third-quarter 1982						Nine-months 1982					
			Change from 1981		Profit margin[b]				Change from 1981		Profit margin[b]	
	Sales	Earnings[a]	Sales	Earnings	1982	1981	Sales	Earnings[a]	Sales	Earnings	1982	1981
Air Products[c]	$ 415.6	$ 26.9	3%	−7%	6.5%	7.1%	$1195.4	$ 80.4	−1%	−14%	6.7%	7.8%
Allied[d]	1514.0	881.0	−2	1	5.4	5.2	4723.0	226.0	—	−10	4.8	5.3
American Cyanamid[e]	861.2	27.1	−8	−48	3.1	5.6	2607.8	90.3	−4	−39	3.5	5.5
Chemed[f]	64.2	3.9	−1	−19	6.1	7.4	188.9	13.1	1	−15	6.9	8.2
Dow Chemical[g]	2548.0	35.0	−13	−73	1.4	4.4	8057.0	329.0	−9	−34	4.1	5.6
Ethyl	410.7	23.0	−8	8	5.6	4.7	1231.0	68.0	−7	1	5.5	5.0
FMC	863.0	29.0	2	−29	3.4	4.8	2612.4	106.7	5	−13	4.1	4.9
First Mississippi	49.2	5.0	14	−27	10.2	15.8	163.0	9.7	−11	−25	6.0	7.1
H. B. Fuller	79.6	2.5	−5	−34	3.1	4.6	235.2	6.6	−5	−36	2.8	4.2
GAF[h]	179.2	8.8	1	def	4.9	def	482.1	−1.3	−9	def	def	0.4
B. F. Goodrich[i]	795.4	−0.1	−3	def	def	1.8	2300.0	−3.5	−4	def	def	1.9
W. R. Grace[j]	1441.9	44.4	−9	−31	3.1	4.0	4535.3	200.4	−5	−19	4.4	5.2
Hercules[k]	602.0	25.6	−13	−29	4.3	5.2	1690.0	69.8	−9	−42	3.7	5.8
Philip A. Hunt	29.4	1.0	7	−41	3.4	6.2	89.2	5.0	9	9	5.6	5.6
International Minerals	356.5	24.4	−12	−32	6.8	8.9	1176.4	52.6	−19	−55	4.5	8.0
Loctite	53.1	3.6	−3	−29	6.8	9.4	162.3	10.1	−3	6	6.2	5.7
Lubrizol	199.0	11.9	−10	−50	6.0	10.8	615.7	41.1	−9	−45	6.7	11.0
Monsanto[l]	1504.5	71.0	−8	27	4.7	3.4	4859.6	304.7	−10	−6	6.3	6.0
Nalco Chemical	160.1	17.6	−5	−17	11.0	12.6	485.0	49.4	−1	−18	10.2	12.2
National Distillers	448.4	15.5	−7	−49	3.5	6.3	1377.7	61.9	−9	−38	4.5	6.6
Olin	433.9	11.2	−11	−37	2.6	3.6	1407.8	56.6	−10	−28	4.0	5.1
PPG Industries	840.0	43.7	−1	−16	5.2	6.2	2470.0	113.5	−3	−34	4.6	6.7
Pennwalt	232.4	7.3	−10	−46	3.1	5.3	732.8	24.5	−9	−38	3.3	4.9
Reichhold Chemicals	197.4	1.1	−20	−71	0.6	1.6	630.2	8.2	−15	−47	1.3	1.8
Rohm & Haas[m]	441.3	17.2	−1	−20	3.9	4.8	1444.6	61.2	−2	−26	4.2	5.6
Stauffer Chemical	283.6	14.1	−17	−1	5.0	4.2	1219.5	113.4	−10	−10	9.3	9.3
Union Carbide[n]	2164.1	60.5	−11	−61	2.8	6.4	6775.6	269.5	−13	−47	4.0	6.5
Williams Cos.[o]	380.6	−0.3	−21	def	def	2.9	1332.4	25.0	−14	−72	2.2	6.7
Witco Chemical[p]	331.8	8.6	2	−10	2.6	2.9	1001.7	21.5	2	−22	2.1	2.8

[a] After-tax earnings from operations excluding extraordinary and nonrecurring items. [b] Earnings as a percentage of sales. [c] Excludes $2.8 million extraordinary gain in third-quarter 1982 and $6.7 million nonrecurring charge for nine-months 1982. [d] Excludes $38 million gain in third-quarter 1981. [e] Excludes $2.9 million nonrecurring gain in nine-months 1982. [f] Excludes $5.3 million nonrecurring gain in third-quarter 1981. [g] Excludes $57 million extraordinary gain in nine-months 1982. [h] Third-quarter 1982 excludes $7.0 million nonrecurring gain. [i] Excludes nonrecurring gain of $8.5 million in third-quarter 1981, $4.4 million in nine-months 1982, and $30.8 million in nine-months 1981. [j] Excludes $33.7 million nonrecurring gain in third-quarter and nine-months 1981 and $65.1 million nonrecurring gain in nine-months 1982. [k] Excludes $6.2 million nonrecurring gain in third-quarter 1982. [l] Excludes $67.7 million nonrecurring gain in third-quarter 1981. [m] Excludes $9.0 million nonrecurring charge in nine-months 1981. [n] Excludes $10 million nonrecurring gain in third-quarter 1982; third-quarter and nine-months 1981 figures are on a pro forma basis. [o] Excludes $3.7 million nonrecurring gain in nine-months 1982. [p] Excludes $1.0 million charge in third-quarter 1982 and $0.6 million gain in nine-months 1982.

manufacturer, Loctite, posted an earnings drop of 29% to $3.6 million and a sales drop of 3% to $53.1 million.

Lubrizol, another specialties company with a long history of stellar earnings performances, saw profits decrease to $11.9 million in the third quarter, 50% less than in the third quarter last year. Sales dropped 10% to $199 million. According to Lubrizol chairman Lester E. Coleman, earnings and sales declined because of lower product shipments and selling prices.

One of the biggest third-quarter earnings drops reported thus far is Reichhold Chemicals', whose profits fell 71% from last year's quarter to $1.1 million. The company's sales dropped 20% to a little more than $197 million.

Not all of the big declines were at the smaller firms, however. For instance, Union Carbide's third-quarter earnings dropped 61% from a year before to $60.5 million, and its sales dropped 11% to $2.16 billion.

W. R. Grace's third-quarter earnings fell 31% to $44.4 million as sales sagged 9% to $1.44 billion. Grace's chairman and chief executive officer, J. Peter Grace, says, "Looking ahead, the economic signals are mixed, making it difficult to formulate a conclusion as to when a sustainable, noninflationary upturn may commence."

At Dow Chemical, president Paul F. Oreffice has some hope for the future but not about the current business scene. "Economic conditions continue to hamper our business recovery on nearly a global scale. The grim economic facts of life persist, and no meaningful signs of recovery are apparent. . . . Economic conditions are ripe for a business improvement, considering the declining trend of inflation and interest rates. However, we need a shift in consumer confidence to spur spending. I don't believe this change will occur overnight, and any economic recovery will be gradual." Dow had one of the worst third-quarter performances with a 73% earnings drop.

Other leading chemical executives are just as noncommittal, and for good reason. For although financial markets have improved notably in the past half year, manufacturing industries such as chemicals have yet to follow suit. A few chemical areas such as thermoplastics have turned up slightly since last winter, but for most of the industry, there's no sign yet of recovery. And until recovery begins, earnings will continue downhill. ◻

Environmental issues color election politics

Economic issues are highlighting these off-year elections, but environmental concerns are shading some of them. The recent Sierra Club report faulting the Environmental Protection Agency's custodianship of hazardous dump-site cleanup under Superfund and EPA's response to the charge is a case in point.

Last week the Sierra Club charged EPA with lagging 60% behind schedule in implementing Superfund. The environmentalist group said that the funds budgeted for cleanup are as much as 50% less than what EPA calculated were necessary in 1980, when Superfund legislation was being drafted. Obligated funds for cleanup are 37% below those targeted in 1980. And funds actually spent on cleanup, though unknown, are estimated by the group to be "a small fraction of the funds obligated."

More pointedly, the Sierra Club charges the Reagan Administration with balancing the budget, in part, on the back of Superfund. By the end of fiscal 1983, the Superfund kitty—fees collected on oil and chemical feedstocks—will be a fat $370 million, the group estimates. By not using these funds to clean up abandoned waste dumps and by treating the funds as regular government income, the Administration is using them to offset the federal deficit, the group contends.

Sensing that the report was political fodder, EPA hastily arranged a press conference to spotlight its Superfund achievements and to announce a $7.7 million settlement with 24 major corporations to clean up the Seymour, Ind., hazardous waste dump site. Under the agreement, these private funds will be used to remove 60,000 rusting drums, 98 bulk storage silos, and contaminated soil.

Rita M. Lavelle, assistant EPA administrator for hazardous waste, says the Seymour settlement "is proof that our approach is working." She calls the Sierra Club report "inadequate, irresponsible, and totally inaccurate."

The hazardous waste issue isn't the only environmental matter with political currency. To the surprise of all parties to the clean air debate, President Reagan has decided to push for revisions to the Clean Air Act in the upcoming lame-duck session. Reagan, his aides say, believes that changes to auto emission standards and to some stationary-source standards could bolster the ailing auto and steel industries. And some contend that the Interior Department is not announcing major changes such as the development of wilderness areas in the Southwest until after Nov. 2, to prevent electoral losses in New Mexico and Arizona. ◻

The 14-acre dump site in Seymour, Ind. is leaking toxic and flammable chemicals

Chicago plans to woo high-tech industries

With many of its traditional industries in a state of decline, Chicago finally has decided to jump on the already crowded high-technology bandwagon. Four high-technology fields have been targeted as being especially suitable for development in the Chicago area: electronics, communications, and computer technology; manufacturing automation, including robotics; biotechnology; and energy management and control systems.

These targets are embodied in the final report of Mayor Jane M. Byrne's "Task Force on High Technology Development," just issued after a year's deliberations. The task force, comprising some 40 local business, labor, education, and government leaders, is headed by Walter E. Massey, director of Argonne National Laboratory. Task force members note that the Chicago area "possesses tremendous scientific and technical resources for high-tech-

Specialty adhesives business holding up well

Commodity adhesives are suffering from economic downturn, but producers of specialty products report record third quarter

Patricia L. Layman
C&EN, New York

For commodity adhesives, this has not been a good year. But for specialty, formulated products, the past year has been good, and the near-term outlook is promising. In fact, one industry observer goes so far as to say that the adhesive industry has held up well under the general downturn of the past nine months. Where the coatings industry will be down probably 10% from the levels of 1981, the adhesives industry will be up a little. Not a lot, of course, but a gain of 2 to 3% given the depressed economy is no small matter.

And for some companies, this year will turn out to be even better than that small increase in business. At a recent raw materials seminar of the Adhesive & Sealant Council, for example, several manufacturers reported that the third quarter of this year, in particular, would be their best ever. Not all producers reported results that good, but for those few who were singing the blues, far more were predicting that 1982 would be a good year for them.

The key seems to be "specialty." Even in a specialties world such as adhesives, producers who carve out special areas with tailored products wind up doing better than producers whose materials would be classified more as commodities. And one can roughly define the field of specialty adhesives to open a lot of room for product differentiation. According to consultants at Chemical Marketing Services, Cincinnati, the total demand for film-forming resins—excluding natural products such as starches and dextrin, and high-volume commodity adhesives such as urea-formaldehyde used pretty much as is—will be nearly 2.5 billion lb this year. By the time these resins are compounded into finished adhesive formulations, the volume rises to about 3.3 billion lb.

Adhesives at a glance

Sales: about $2.2 billion in 1982, for specialty adhesives, at manufacturer's level

Growth: 6 to 8% per year in dollar volume, and 5 to 6% per year in poundage, through the decade

Manufacturers: Diffuse, unstructured industry with probably close to 1000 manufacturers and formulators. The top eight producers—Avery International, Borden Chemical, Du Pont, H. B. Fuller, Loctite, National Starch & Chemical, 3M Co., and USM's Bostik Chemical—account for about 30% of output.

Principal adhesives by type: Synthetic resins 50%, natural resins 40%, sealants and caulks 10%

Principal adhesives by end-use: Paper products 49%, wood products 18%, sealants and caulks 10%, other markets 23%.

That 2.5 billion lb of adhesives is about the same size as the total demand for film-forming resins in the industrial-coatings business. However, with coatings limited to a growth rate not much better than that of the gross national product, roughly 2 to 3% per year, use of synthetic adhesives is growing at better than twice that clip. And there are a number of the synthetic resins which, as a group, are growing at more than three times the overall adhesives-industry rate.

Chief among them are acrylics, anaerobics, cyanoacrylates, epoxies, polyamides, polyesters, polyethylenes, silicones, urethanes, and vinyl acetate copolymers. For these resins, the major attraction is the ability to tailor or modify the resins for special applications, particularly by forming selected copolymers, and the increasingly important ability to be compounded into water-borne systems.

Air-pollution regulations have forced adhesives makers and users to give more and more attention to nonsolvent systems. Rising energy costs and raw material costs have added to the impetus. Complicated solvent-recovery systems and incineration units are costly and often unwieldy, so users are getting help from suppliers of emulsion and dispersion formulations, 100%-solids hot-melt compounds, to some extent compounds that cure upon exposure to ultraviolet or electron beam radiation, and products that, if not solvent-free, are at least lower in solvents and higher in solids than before.

That much was clear from the Adhesive & Sealant Council's meeting in Chicago earlier this month. Of the nine products introduced at the seminar, four were aimed at the aqueous-formulation adhesive maker. Others were specialty modifiers—thickeners, for example, or solvent extenders—and block copolymer solids systems.

For example, raw-materials suppliers played on the virtues of vinyl acetate as an adhesive: ability to adhere to many surfaces, controlled amount of tack or stickiness, adhesion upon initial contact, and the like. Perhaps because they are components in such everyday items as adhesive mending tape, the labels on the backs of convention tags, and masking tape, pressure-sensitive adhesives tend to be ignored or downplayed. But they make up a respectably sized segment, probably about 15%, of the nearly 3.5 billion lb-per-year market for formulated synthetic adhesives. And they have one of the soundest futures in terms of growth rates in the industry, at probably more than 10% per year through the 1980s.

Thus, there is a considerable attraction for suppliers, particularly of acrylic systems. That's so even though a little adhesive goes a long way, in effect limiting the market for raw-material suppliers. In comparison with other adhesives that might be troweled or sprayed onto a carpet backing or tile backing, for example, at up to 150 sq ft per gal, a pressure-sensitive adhesive will be deposited on its backing substrate at as much as 10 times that coverage per gallon.

Performance modifiers that meet the special requirements of latex systems have become especially important. Thickeners, for example, must be effective at the certain pH ranges desired; mildewcides must be effective in combating microbial growth that can thrive in aqueous formulations.

Vinyl acetate formulations are getting steady attention from manufacturers, a point that has kept demand fairly constant for this key monomer over the past several years (C&EN, Aug. 2, page 9). Again, the strongest markets for the product are in specialities—especially with copolymers, such as acrylic or ethylene. As one industry marketer notes, the economics of vinyl acetate and its basic adhesive properties make it an ideal base for aqueous formulations. And it is relatively easily tailored for other more specific properties, so, "so much the better," this marketer adds.

Similarly, researchers are trying to work the bugs out of formulations of urethane aqueous systems. Urethane dispersions tend to be high priced; "That's where the dialogue stops and you have to retreat for a while," one marketer says. One prospect, however, is blending the urethane dispersions with other aqueous systems, to improve base performance and absorb some of the cost differential. The blend could go from 20% urethane-80% copolymer to a 50-50 ratio, to get any noticeable contribution from the urethane.

From one specialty resin to another is a short step for adhesive chemists, especially with resins such as acrylics and urethanes. Besides urethanes in aqueous systems, for example, companies are putting substantial emphasis on developing structural urethane adhesives—copolymers with anaerobic adhesives, for example. The urethanes lessen the brittleness and improve the tensile strength of the anaerobics; some marketers of anaerobics, in fact, contend that they have anaerobic formulations whose properties equal those of epoxy adhesives for structural bonding.

Hot-melt adhesive emerges from extruder at Borden Chemical's Louisville plant

That's not saying that, with all the fuss about aqueous and other nonsolvent systems, no attention is being given to solvent-borne formulations, which are still, by and large, the mainstay of the adhesive industry. However, most of the R&D work features ways to formulate away from the aromatic solvents, and lessen the total solvent concentration, to raise the concentration of solids.

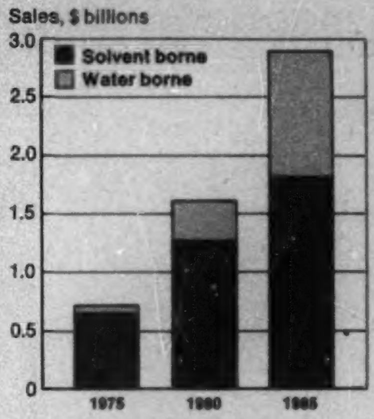
And sometimes the work can involve some sophisticated chemistry. Take, for example, Shell Development Co.'s "spaghetti and meatballs" theory on formulating clear sealants out of block copolymer rubbers. Such sealants are normally opaque, Shell researchers agree, because the materials added—other resins, oils, plasticizers, and the like—are of differing refractive indices from those of the polystyrene and the elastomer (for example, polyisoprene, polybutadiene, or polyethylenebutylene) in the block copolymer.

As Shell chemists see it, polystyrene is on either side of an elastomer midsegment, in a long strand. The strands of the copolymer cluster around rather like strands of spaghetti, with the polystyrene ends clustering together in domains—the meatballs of the theory.

The domains are spherical, notes Geoffrey Holden, a Shell researcher in block copolymers, with an effective diameter of less than the 200 Å for typical polystyrene segment molecular weights. Additives compatible with the polystyrene phase in the thermoplastic copolymer are absorbed into the polystyrene domain, without scattering light. Similarly, additives compatible with the elastomer midsegment disperse in that phase with no light scattering. Materials incompatible with both the polystyrene and elastomer, or compatible with both, tend to form a separate phase, agglomerating together, picking up and scattering light, with the result an undesirably opaque product.

Styrenic block copolymers are one of the basic resin families important for hot-melt adhesives, 100%-solids systems melted for application, which seal or bond as they cool. However, ethylene-vinyl acetate copolymers make up more than half of all hot melts, estimates supplier U.S. Industrial Chemicals. U.S.I. predicts that this segment of the business will account for about 400 million lb by 1985, up from 310 million lb in 1980.

Latex products taking over pressure-sensitive adhesives



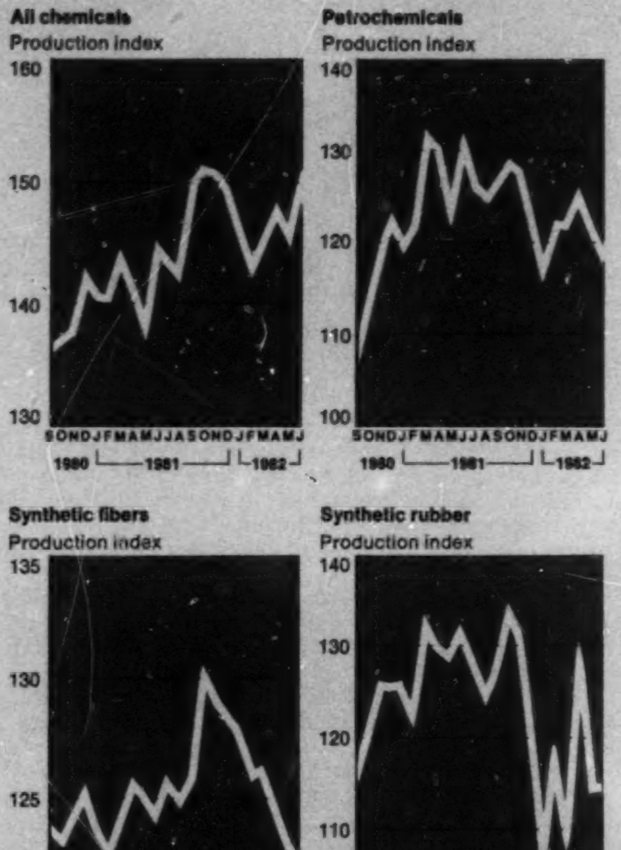
Sources: Hardman, C&EN estimates

Packaging was the largest consumer of hot melts, accounting for some 53% of the total in 1980, but U.S.I. predicts that this will fall to about 47% by 1985. Packaging applications are maturing, the company says, and nonpackaging applications, such as automotive, textiles, electrical equipment, disposables, and furniture, will be growing at a much faster rate over the next few years.

That's important for adhesives makers who want to keep their markets growing. Given the economy, it's probably easier said than done to find new growth areas, but developments in other product businesses help. In the auto industry, for example, an industry not particularly thriving at present, increasing use of plastics has set up increasing demand for adhesives—plastics can't be riveted or welded as metal can. And the booming popularity of plastic beverage bottles has opened a new market for labeling adhesives that have the ability to stick to plastics.

Opening up of these growth areas will help U.S. consumption of adhesives and sealants exceed 15 billion lb in 1995, says Predicasts, a consulting firm in Cleveland. In fact, the company adds, substitution of adhesives for other fastening techniques, and the higher cost of the specialty synthetic adhesives will gain a 55% share of total fastener dollars by 1995, up from 31% in 1979. □

Japanese chemicals continue to be depressed



Note: Base year for all indexes, which are seasonally adjusted, is 1975 = 100.
Source: Ministry of International Trade & Industry

The basic weakness and vulnerability of Japan's petrochemical industry continues to be painfully apparent.

At the end of June, the production indexes for petrochemicals, synthetic fibers, synthetic rubber, plastics, and fertilizer were lower than they were the year before. And in June 1981, all of these indexes were lower than the year before that.

The problems are well documented: depressed markets at home and abroad, high feedstock prices that put the industry at a competitive disadvantage against foreign companies, declining exports and increasing imports, excess capacity, and little or no profits.

Overcoming these problems won't be easy. Rationalization or antirecession cartels are the primary tools that Japan intends to use to solve the structural problems of its petrochemical industry and other ailing basic industries, such as aluminum, textiles, and pulp and paper.

Recently, Japan's Fair Trade Commission authorized an antirecession cartel for 12 ethylene producers. The cartel will operate for a 5.5-month period, from Oct. 16, 1982, to March 31, 1983. During that time, the cartel, the first for ethylene in Japan in 10 years, will limit output to 1.55 million metric tons—3.6% less than during the corresponding period of 1981–82. More significantly, that output level is only 56% of Japan's rated ethylene capacity, which is less than the operating rate that producers have been averaging so far this year.

Very few doubt that some mechanism is needed to pare excess ethylene capacity. However, some experts already doubt that the 12 producers who previously fought tooth and nail for market share will be able to make the cartel work. One reason for these doubts is Japan's August ethylene production, which hit 330,000 metric tons—the highest monthly output this year and only the second time output has reached that level since June 1980. Certainly, the market didn't require that much ethylene. Production was down more than 4% during the first half of the year and averaged less than 300,000 metric tons per month over that time span.

The prevailing explanation is that producers, anticipating that an antirecession cartel was likely if not inevitable, boosted output in a last competitive stab at market share.

Meanwhile, the petrochemical industry's problems extend beyond ethylene. The Chemical Industry Committee of the Industrial Structure Council estimates that by 1985, overcapacity within the petrochemical industry will range from 20 to 35%. Typical of the results are overcapacity of 21 to 30% for polyethylene (depending upon type), 35% for acrylonitrile, and 26% for polyvinyl chloride.

The Chemical Industry Committee's estimates are based upon its own projections of petrochemical imports. But the Ministry of International Trade & Industry thinks that those projections might be low. Thus, future overcapacity might be higher than expected.

MITI could be right. During the first half of the year, Japan's petrochemical imports topped exports for the first first-half deficit (volume basis) in the history of its petrochemical industry.

Earl Anderson, New York

Handling of rail chemical spill praised

Thanks to safety devices, insulation, and preparedness by authorities, recent train derailment of chemical tank cars caused no injury, death

Rebecca L. Rawls
C&EN, Washington

Although the public at large may view things differently, the rail and chemical industries are quietly proud of what happened in Livingston, La., in the last days of September and the beginning of October.

It would have been better, of course, if the 101-car Illinois Central Gulf freight train had not derailed in the predawn hours on Sept. 28, strewing 43 of its cars along the main road of that rural Louisiana town some 30 miles east of Baton Rouge and forcing 3200 people to evacuate their homes, some for as long as two weeks.

But, as the industry is quick to point out, train derailments involving hazardous materials are very rare—99.99% of rail shipments of hazardous materials are delivered without incident, which is one of the best records in transportation. And the record is getting better. The number of releases of hazardous materials from rail cars has fallen by some 40% since 1978 to just over 200 in 1981. Injuries from such incidents have dropped more than 50% over the same period.

"We can never totally prevent all accidents," says Geraldine V. Cox, vice president and technical director of the Chemical Manufacturers Association, and her words echo the feelings of almost everyone involved in hazardous materials transport. "Our job is to minimize the number of accidents and to give as large a margin of safety as is possible each time an accident occurs," she says.

It is in this area of safety margins that the industry feels proud about the Livingston derailment. Safety devices retrofitted onto the cars of the derailed train worked as they were designed to do. Thermal insulation, designed to keep tank cars from exploding for several hours in even the most dramatic accident, lasted not just for hours, but for days. True, two cars did explode—or thermally rupture as the jargon of the trade calls it—but not before area residents had been evacuated and police and firefighters had had a chance to get ready for such an explosion.

Two aspects of the Livingston incident in particular are drawing praise from industry observers. These are the effectiveness of safety devices now required on tank cars that carry hazardous materials, and the preparedness of Louisiana authorities who took charge of the accident. "I've been to too many derailments," says Thomas Phemister, head of the Association of American Railroads' bureau of explosives, "and this one was the best coordinated that I've ever been to."

"Frankly, I was impressed with the way the incident was handled," says John C. Zercher, director of the Chemical Transportation Emergency Center (CHEMTREC) run by CMA. "Unquestionably, this was the worst derailment I've been involved with, both in terms of the amount of hazardous material involved and the mix of different kinds of materials that presented different hazards," Zercher says. "It was one big social disruption—nobody could question that—but there were no injuries except for one man who was bitten while feeding a dog."

Although railroad investigators and those from the National Transportation Safety Board still are working to piece together all the details of what caused the derailment at Livingston, much of the picture is clear. The train was on a return run from Baton Rouge to McComb, Miss., traveling on straight, level track. Seventeen of its cars were empty, and the rest contained quite a list of potentially hazardous materials: seven cars of vinyl chloride and one of methyl chloride, a close chemical relative; one car each of metallic sodium, styrene, and tetraethyllead; three cars of toluene diisocyanate; 11 of phosphoric acid; and one of sodium hydroxide.

According to the railroad, the derailment was caused by a complete break in the center pin that held the wheel assembly onto an empty, open-topped gondola car. The break was an old one—it already was rusty—but located in a spot that would not be noticed except in an inspection of internal body parts. Because the pin was broken, the wheels were able to work out from under the body of the car.

Further investigation unearthed

UPI photo

Illinois Gulf Central freight train accident, which resulted in the spilling of hazardous chemicals, was caused by a break in the pin that holds the wheels on several irregularities surrounding the run. The train probably was speeding, traveling at about 40 mph in a zone with a speed limit of 25 mph. The engineer and brakeman were seen drinking earlier in the evening, although whether they actually were intoxicated at the time of the derailment is not known. In any case, the train probably was being driven not by the engineer, but by a clerical worker with the railroad who was not even authorized to be in the engine's cab. Louisiana state police arrested the clerical worker, along with the engineer and the brakeman. They are charged with reckless handling of hazardous materials, a felony offense that carries a sentence of a $5000 to $10,000 fine or five to 10 years imprisonment, with or without hard labor, or both.

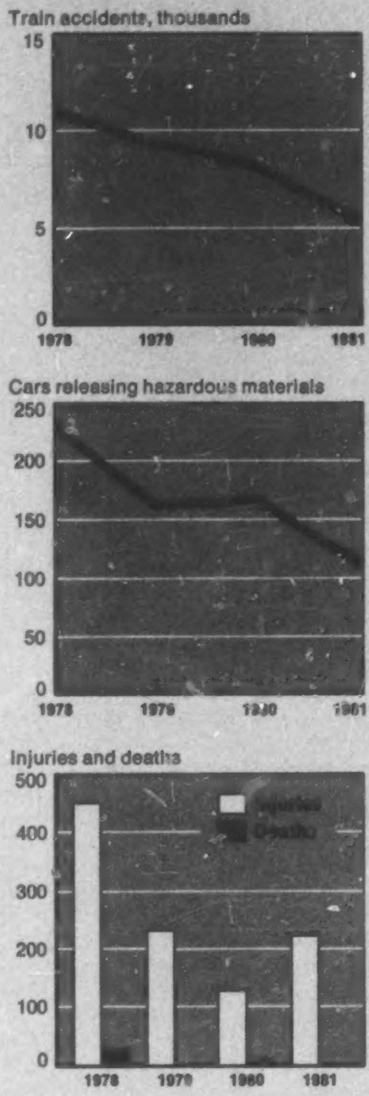
It's quite likely that neither the drinking nor the clerical worker's possible operation of the train had any effect on the derailment. The crew "did exactly what they were supposed to do when the emergency occurred," according to a police spokesman, and they didn't give people they dealt with the impression they were intoxicated.

In fact, once the train left the tracks, no one seems to have anything but praise for the behavior of everyone involved in the incident. "I've never seen an incident where everyone cooperated so thoroughly," says AAR's Phemister, who arrived on the scene on the day of the derailment to provide expert assistance and stayed on for the first two weeks of the cleanup. "The big difference here was that the police officers [who were in charge of the operation] had had hazardous materials training. They knew what was being talked about by the chemicals and hazards specialists, so they could participate fully in all of these discussions," Phemister says.

Another key factor, according to Cox and other observers, is that the police were able to take charge quickly of the overall emergency response effort. "In some states, a lot of time is lost at the very beginning of an incident fighting over who's in charge," Cox says. Louisiana state law gives this responsibility to the state police, who, under the direction of Capt. Billy Poe, responded rapidly and appropriately.

The police were well prepared to take charge. Only a month earlier they had taken part in a hazardous materials drill in New Orleans. Last summer some of the police force attended a hazardous materials training session at the Denver (Colo.) Fire School, and last April they were part of a conference in Milwaukee on coping with railroad hazardous materials spills. The conference was sponsored by AAR, CMA, the Environmental Protection Agency, and the Coast Guard.

Rail incidents involving hazardous materials fall



Source: Association of American Railroads

The team headed by Poe included, in addition to state police and local firefighters, representatives of the Illinois Central Gulf railroad, Phemister and others from AAR's bureau of explosives, Coast Guard and EPA representatives, and representatives of the chemical companies whose shipments were on the train.

The railroad hired an environmental monitoring firm, IT Corp., to keep track of chemical concentrations at the site and to advise emergency personnel on the sort of protection they would need to do their work. The company also monitored for the spread of environmental contaminants from the accident site.

Twice a day helicopters flew over the site photographing the exact positions of the train cars. Strategy for cleaning up the site involved mostly pulling undamaged cars away from the accident site and letting the remaining cars burn to minimize the environmental consequences of their leaking contents. In several cases, cars were ruptured deliberately and their contents burned in a controlled manner since this was the surest way to keep their contents from contaminating the local area. The phosphoric acid was neutralized with a base and the reacted material hauled away.

Another important factor at Livingston was the recently implemented changes in the specifications for tank cars that carry hazardous materials. These changes arose from a series of recommendations made by a 1978 interindustry working group on rail transport of hazardous materials.

The changes demonstrated their value at Livingston, says CMA's Cox, who served on the 1978 task force and presently is on the task force that succeeded it. Besides CMA, the task force has members representing AAR and the Railway Progress Institute, an association of tank car owners.

Among the recommendations of this task force was a new kind of connection between cars called shelf couplers. The ordinary coupling between train cars resembles two hands joined together by curled fingers. In a shelf coupler, the thumbs of each hand rest on the little finger of the opposite hand. The effect is to prevent a vertical motion from uncoupling the cars. Once uncoupled, couplers act like battering rams to punch holes in the ends of adjacent tank cars, so keeping them from breaking free is an important safety improvement.

Another recommendation that addressed the same problem called for tank cars to be fitted with head shields, which are half-inch steel plates that fit to the lower half of the ends (or heads) of tank cars, to make it much more difficult for couplings to punch through the ends of the cars. Cox says there were no head punctures in the Livingston derailment, evidence that these two devices did their job.

Cars carrying flammable materials also have been retrofitted with extra insulation designed to delay their blowing up long enough for emergency workers to prepare for it. All of the cars containing flammable gases on the Livingston train had this extra insulation. Although two cars did thermally rupture, the first one (containing tetraethyllead) did not blow up with the tremendous explosive power that can accompany such an occurrence, and the second (containing vinyl chloride) did not explode until two days after the fire started. "In the same situation 10 years ago [before the cars were retrofitted]," Zercher says, "the seven cars that contained vinyl chloride almost certainly would have gone up in the first four and a half hours of the [fire's duration]." As it was, only one of these cars blew up at all and that was well after people had been evacuated from the area.

Other recommendations of the 1978 task force included development of large-scale training programs for emergency response personnel, such as those in which the Louisiana police participated, and development of a permanent teleconferencing "bridge" at CHEMTREC. This system allows on-site personnel to be in simultaneous communication with experts at several chemical companies who can advise them on particular hazards; it was used several times during the emergency.

Although the firefighters have left and the residents of Livingston have returned to their homes, the Livingston derailment is by no means over. Environmental monitoring of the area continues, for example. Reports so far indicate no adverse residual levels of phosphoric acid, one of the most important potential environmental hazards. And the lead levels in Livingston, which might have been elevated due to the explosion of the car containing tetraethyllead, are lower than control readings in an adjacent county.

The railroad is continuing its investigation of the incident, focusing particularly on the conduct of its employees. The National Transportation Safety Board, too, is continuing its investigation of the causes of the incident. And the state of Louisiana continues to develop its case against the people who have been arrested.

C&EN staff photo

Zercher: one big social disruption

The question of whether alcohol was a contributing factor to the derailment is one of particular concern to the safety board. There currently are no federal regulations forbidding railway personnel from drinking while on the job or from driving a train while intoxicated—a situation that the safety board has been on record as wanting to change since 1974. "The record of alcohol misuse in the railroads is incredible," says Ira Furman, a spokesman for the board. He cites, among other data, a 1978 study conducted for the Federal Railroad Administration that found an average of 33 railway workers every day who considered themselves to be "very drunk" on the job. About 12% of the 234,000 railroad workers surveyed said they drank at least once while on duty in 1978.

Another issue that may have affected the Livingston incident that the safety board is concerned about is the arrangement of full and empty cars on a train. At present, the cars on a train are arranged according to the order in which they will be dropped off at their destination. Thus, it is quite likely that cars containing the same hazardous material will be scattered throughout a train with no regard to the contents of adjacent cars. (The only exception is a requirement that cars that contain railroad personnel be separated from those containing hazardous materials by at least five cars.)

None of the concerned parties—the chemical shippers, the railroads, and the safety board—is seriously considering trying to group chemical tank cars by their content on freight trains; the rearrangements that procedure would entail at each transfer point would be too formidable. But the safety board is concerned about the differences between full cars and empty ones in a derailment. It is investigating the effect of a car's weight on its crash dynamics to see if trains might be safer if the empty cars were grouped together and arranged so that loaded cars would not crash into them.

The interindustry task force that recommended many of the tank car changes that were so useful at Livingston presently is in a "second incarnation" as Cox calls it. The group was reformed last summer to suggest further improvements in the safe transportation of hazardous materials and the handling of spills.

Although its report is not expected for several months, Cox says the task force this time is not really focusing on major derailments like the one at Livingston. Rather, it is directing its attention to the small spills that account for almost all of the incidents that occur. Although major derailments attract the most public attention, Cox says, most spills are much smaller and involve only the breakage of a bottle or two or a single leaky container. The task force is looking specifically at areas such as the loading process, inspection procedures, and the small-scale releases that sometimes occur at safety valves. It also is considering whether the rail and chemical industries need to improve their public image when major incidents do occur, perhaps by having a public relations person at the scene. □

New system eliminates spectral interferences

A just-introduced atomic absorption spectrometer, Instrumentation Laboratory's Video 22, employs a new background correction system that, the company says, offers significant advantages over deuterium-arc and Zeeman-effect systems.

In the new approach, the AA instrument's hollow cathode lamp serves as its own background corrector. As chemists have known for a long time, when a high current is passed through a hollow cathode lamp, its emission line is broadened and atomic absorbance by the sample is reduced greatly. The phenomenon, called self-reversal, generally is regarded as something to be avoided.

However, it occurred to Stanley B. Smith, director of R&D for IL's analytical instrument division, and Gary M. Hieftje, a chemistry professor at

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Profitable Stauffer Chemical sticks to success formula
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Membrane technology

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Cover: Phase diagram, developed by C. A. Smolders at Twente University of Technology, the Netherlands, and his collaborators, helps show what happens when a dissolved polymer is treated with a mixture of solvent and nonsolvent during the membrane fabrication process

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down capacity was in ethylene, with some 3.9 billion lb shut down. The largest number of plants or units closed was in propylene, with 11 plants shutting down some capacity.

Despite those closedowns, however, overall capacities have risen. For example, since 1978, ethylene capacity has risen 16% to 38 billion lb per year; propylene has risen 17% to 20 billion lb; butadiene 5% to 5.1 billion lb; benzene 3% to 1.83 billion gal per year; and toluene 8% to 1.3 billion gal. Only chlorine capacity declined, falling 2% to 26.2 billion lb.

By Eldib's analysis, the 10 largest-volume producers account for more than half the total capacity for each of the major petrochemicals and for chlorine. For ethylene, for example, the top 10 have 53% of the total 38 billion lb-per-year capacity in the U.S. Butadiene is an even more concentrated industry, with the top nine producers having 65% of the 5.1 billion lb-per-year capacity in the U.S.

In the future, though, those top producers—as well as other producers—will be facing a dramatically different competitive picture. From the present average 65% capacity utilization rate for petrochemicals, by Eldib measures, use will begin rising, fueled by a modest but steady growth in demand of 3 to 4% per year over the next few years. Given present capacity, the demand line will cross supply in 1990 or 1991, with the present situation of excess capacity becoming unmet demand.

New capacity therefore will be needed—but it may very well not be built in the U.S. Petrochemical complexes being planned and built outside the U.S.—for example, in Mexico, Canada, and Saudi Arabia—may be able to produce cheaply enough to provide tough competition. □

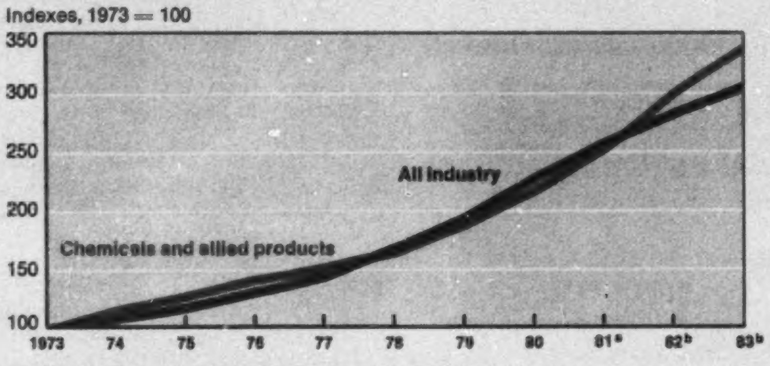
Chemical R&D funding up again in 1983

All year long, questions have lingered whether the U.S. chemical industry finally would relent in the breathless pace of its research and development funding gains in recent years. After all, the severe recession the industry has been going through has hobbled many other spending programs.

Chemical firms' R&D funding pushes up strongly in 1982 and 1983 compared to other industries . . .

$ Millions	1983 projected	1982 projected	1981 estimated	1980 actual	% change 1982–83	1981–82
Chemicals and allied products	$ 6,530	$ 5,730	$ 4,900	$ 4,201	14%	17%
Instruments	3,325	2,920	2,540	2,139	14	15
Electrical equipment	7,685	7,050	6,300	5,414	9	12
Machinery	6,885	6,375	5,900	5,221	8	8
Motor vehicles	4,690	4,470	4,300	4,240	5	4
Aircraft and missiles	3,185	3,250	3,100	2,730	−2	5
Other	7,925	7,480	6,840	5,995	6	9
TOTAL	$40,225	$37,275	$33,880	$29,940	8%	10%

. . . and pulls ahead of all industry's long-term R&D funding growth



a Estimated. b Projected. **Source:** National Science Foundation from industry surveys

No such thing, concludes the National Science Foundation after its first poll, expected to become annual, of industrial companies to get early estimates of coming R&D budgets for work in the U.S. NSF's Industry Studies Group has started the new surveys to supplement its existing R&D studies, which generally run two years behind the current pace.

From data gathered last spring, the Industry Studies Group projects R&D funding gains of 17% in 1982 and 14% in 1983 for chemicals and allied products companies (including drug firms). As R&D budgets go, these percentages are large and will keep funding comfortably ahead of R&D inflation.

NSF's projections are not far from C&EN's own data on expected R&D budgets this year at the leading basic chemical producers. C&EN's latest tally projects total R&D spending will be up 18% in 1982 after a 20% increase in 1981 (C&EN, June 14, page 55). C&EN expects to publish its 1983 survey early next year.

The Industry Studies Group comments that the chemical industry is expected to exhibit the highest percentage increases in company R&D spending from 1981 through 1983 of any major R&D-performing industry. The average gains through all industries are projected at 10% in 1982 and 8% in 1983.

The studies group attributes the strong showing by chemical companies to several factors. Chemical firms have increased R&D dollars to explore recent breakthroughs in biology and biochemistry, especially in genetic engineering. Also, many firms are diversifying rapidly into new product areas such as agricultural chemicals and drugs, where entry requires substantial R&D investment.

Drug companies echo the optimism of chemical firms. NSF estimates R&D spending at drug firms up 20% in both 1982 and 1983. Reasons behind this growth are recent major medical breakthroughs, marketing opportunities in new and evolving technologies, and U.S. and foreign competition. Drug firms also regard the new federal tax credit for increased R&D expenditures and the movement of the Food & Drug Administration toward shorter drug approval times as positive influences on increased R&D budgets for U.S. operations. The response to the tax measure contrasts with a general lack of excitement over it at many companies in other industries. □

European petrochemicals outlook not all bad

Demand for styrene likely to grow about 2% annually; butadiene and other unsaturated C-4s also are forecast to do well

All wasn't gloom and doom at this year's European Chemical Market Research Association's meeting in Oslo. Although the near-term outlook for business in general and for petrochemicals in particular hardly can be classed as bright, the 160 attendees gained a modicum of comfort from projections that demand for some products remain firm.

"Styrene has a good future," declares Alan Bateman of Dow Chemical Europe. He concurs in the "fairly widely held view" that consumption in Western Europe will grow about 1.5 to 2% annually over the next five years or so. "While historic rates have been higher, there's still growth predicted," he points out.

European styrene consumption last year was about 5.72 billion lb, most of it used captively by producers. Total demand is expected to move up to between 6.54 billion and 6.84 billion lb by 1990 if the growth rate foreseen materializes.

Bateman doesn't foresee much additional styrene capacity being installed in Europe in the immediate future. This, coupled with a steady, if modest, demand growth augurs well for the operating economics of existing plants.

Like so many other petrochemical operations throughout Western Europe, styrene plants there are running at levels well below their potential, on average about 69% of their design capacity. This could rise to a more economically attractive 84% level by the end of the decade, assuming Bateman's contention that no new units appear on the local scene, and that the projected annual rate of growth materializes.

There now are 10 companies making styrene in Western Europe with a current combined annual capacity of some 7 billion lb. Dow is the biggest. Its units at Terneuzen, the Netherlands, have a total rated capacity of more than 1.5 billion lb annually. Other big names in the styrene producers' league are BASF at Ludwigshafen (1 billion lb); Rheinische Olefinwerke, jointly owned by BASF and Deutsche Shell, at Wesseling, also in West Germany (924 million lb); Montedipe, the petrochemicals arm of Montedison, at Mantova, Italy (770 million lb); and Shell Nederland Chemie at Moerdijk, the Netherlands (715 million lb).

Bateman doesn't expect the Middle East to pose a significant threat to established European producers. "Compared to ethylene capacity, projected [Middle East] styrene capacity is small," he points out—about 1.3 billion lb per year.

"The prime reason for this is that the raw material position [there] does not justify the investment costs," he says. "The only raw material advantage could be in the ethylene cost. However, ethylene contributes only one third by weight of the raw material, whereas benzene constitutes two thirds of the styrene molecule. It is unlikely," he maintains, "that benzene costs from Middle East reformers will show any advantage to benzene produced in Western Europe."

The pattern of European styrene use isn't likely to change significantly from the present profile, Bateman contends. About 50% now goes to make general-purpose polystyrene. A further 19% goes to expandable polystyrene, which "will grow at higher rates than the other end uses through the balance of the decade," he expects. Next in importance follow styrene-butadiene latex and rubbers, 12%; acrylonitrile-butadiene-styrene and styrene-acrylonitrile polymers, 9%; and unsaturated polyester resins, 5%. Miscellaneous outlets make up the 5% or so balance.

Bateman admits to being "fascinated by the replacement of polystyrene by polypropylene," wondering whether further substantial substitution will take place and so bite into the largest single styrene outlet. "Polystyrene will more than hold its own against polypropylene," he predicts. "One reason for my optimism is that expandable polystyrene is capable of greater stimulation than is polypropylene."

Probably more to the point is the projected decline in propylene availability stemming from closure of naphtha crackers to correct for the large ethylene overcapacity, coupled with the trend in Western Europe to shift from naphtha and gas oil as cracked feedstocks to liquefied petroleum gas and ethane with the resultant drop in coproduct propylene.

Butadiene and isobutene supply will remain tight, but *n*-butenes will be more plentiful

Millions of lb	Demand		Annual change	1990 surplus (or deficit)
	1981	1990		
Butadiene	**10,692**	**13,200**	**2.4%**	**—**
Western Europe	2,519	2,860	1.4	660
North America	3,608	4,180	1.6	(286)
Japan	1,276	1,518	1.9	(198)
Eastern Europe	2,420	3,300	3.5	(88)
Rest of world	869	1,342	4.9	(88)
Isobutene	**4,224**	**7,238**	**6.2**	**(264)**
Western Europe	1,342	2,200	5.6	(176)
North America	2,112	3,410	5.5	(1980)
Japan	396	572	4.2	418
Eastern Europe	308	836	11.7	1034
Rest of world	66	220	14.3	440
***n*-Butenes**	**2,574**	**3,080**	**2.0**	**660**
Western Europe	638	814	2.7	550
North America	1,507	1,298	−1.6	(242)
Japan	264	391	4.6	44
Eastern Europe	132	242	7.0	418
Rest of world	33	330	29.2	(110)

Source: BP Chemicals

Admittedly, this trend also will lead to a drop in cracker-derived benzene needed for making styrene. But, as Bateman notes, "Benzene is an internationally traded commodity, propylene is not."

He discounts any widespread use of oil refinery product streams as a propylene source. Such propylene requires upgrading to polymer quality material. The cost of such an upgrading unit with an annual capacity of 396 million lb has been pegged at $20 million. "That's not too much in the size of investments in the petrochemical industry," he acknowledges.

"But it's not the whole story. Propylene is a gas, and it needs special boats, rail cars, or pipelines to move it. An alternative would be to build polypropylene units where the upgraded refinery propylene is produced." Such units don't come cheap, however. It would cost about $70 million for a 165 million lb-a-year polypropylene unit in contrast to $30 million for the same size polystyrene plant, he notes.

The unsaturated C-4s—butadiene, isobutene, butene-1, and butene-2—have considerably better prospects for growth and profitability in Western Europe compared with ethylene, predicts BP Chemicals' Iain Steel. "This bullish forecast is based on modest growth of the synthetic rubbers, and continuing good prospects for isobutene-based products augmented by methyl *tert*-butyl ether (MTBE). *n*-Butene consumption will increase due to demand for butene-1 as a linear low-density polyethylene comonomer."

Global supply and demand of butadiene is expected to remain in balance throughout the decade, growing at an annual average rate of almost 2.4% from last year's 10.7 billion lb to 13.2 billion lb in 1980. Western Europe will continue to outpace local use, supplying the needs of Eastern Europe, Japan, North America, and other areas.

World isobutene demand likely will grow nearly 6.2% per year between 1981 and 1990, outpacing the 2.9%-per-year availability increase. Consequently, an overall supply deficit of 264 million lb will develop by 1990 from last year's surplus of nearly 1.2 billion lb.

Growth in world supply of the *n*-butenes will outpace demand. By 1990, therefore, availability could reach 660 million lb from last year's 264 million lb total. North America will remain in deficit supply throughout the period. However, a declining growth rate there, coupled with increasing local availability, will narrow the gap from last year's 759 million lb to 242 million lb.

The butadiene growth rate forecast of 2.4% per year through 1990 is low compared with the projections of others, Steel admits. But he believes his estimate to be realistic because of the slowing demand for butadiene-based synthetic rubbers. "Some two thirds of butadiene derivatives are consumed in cars and trucks as tires, hoses, etc., so demand closely reflects the fortunes of the transport industry," he notes.

The main isobutene derivatives, MTBE and butyl rubber, also are dependent on the transport industry. Last year, these two outlets consumed 57% of the chemical. The balance went toward making oligomers and polymers used as solvents, oil additives, adhesives, mastics, and other high-added-value materials.

There has been a mixed reaction from the oil companies to the use of MTBE as an octane improver in gasoline, he admits. Aromatics, when they are available, usually are preferred on a cost basis. So the forecast for MTBE use is speculative.

With MTBE, isobutene's overall annual growth rate likely will be 6.2% during the remainder of the decade, Steel believes. "Without this outlet, growth is expected to be 2.4% per year—2% per year for butyl rubber, 3% for oligomers and the various polymers of isobutene, and 4% for lesser outlets, which include some use for methyl methacrylate production, particularly in Japan, in the late 1980s.

"The 2%-per-year growth rate forecast for *n*-butenes demand throughout the decade conceals considerable activity," he notes. On the one hand, there is likely to be a decline in the use of *n*-butenes as a source of butadiene by dehydrogenation. Steel estimates that almost 15% of last year's global butadiene capacity of 16.6 billion lb was based on such dehydrogenation technology. In North America, fully 20% of the 5.4 billion lb butadiene capacity is accounted for by these units.

Steel expects that all butene dehydrogenation units in the U.S. will be closed permanently by the mid-1980s, because they cannot compete on energy terms with butadiene extraction from ethylene coproduct streams. Dehydrogenation plants are likely to be deemed viable only in South America and Eastern Europe, he believes.

The resulting decline in demand for the *n*-butenes will be countered by increased use of butene-1 in linear LDPE. "How fast butene-1 demand will grow is a matter of much debate," he says. "We in BP Chemicals believe that it will be the most cost-effective comonomer in the first phase of linear-LDPE development, but we are working on second generation alternatives."

On the supply side, Steel foresees a slight fall in the ratio of butadiene to ethylene in Western Europe's cracker product streams because of increasing use of lighter cracker feedstocks. Naphtha and gas oil, for instance, yield upward to 16 lb of butadiene per 100 lb of ethylene depending on the cracking conditions. Liquefied petroleum gas, on the other hand, yields less than 6 lb, whereas the amount of butadiene that results from cracking ethane is negligible.

The U.S. trend is opposite to that in Western Europe. The move is toward heavier cracking feedstocks, so the ratio of butadiene in the product streams will be higher than has been the case in the past. On the other hand, the likely closure of butene dehydrogenation plants will reduce the amount of butadiene available from that source. Elsewhere, butadiene production will increase as new petrochemical complexes are brought on stream.

In spite of these changes, Western Europe will remain the world's butadiene supplier, Steel contends. "Despite dependence on the transport industry with its low growth forecast, butadiene worldwide will tend toward balance or tightness," he says. "This means that current price levels will stabilize or move up, with corresponding benefit to producers' economics."

As for isobutene, its primary source in Western Europe and North America will continue to be "raffinate-I," the isobutene-rich fraction following removal of butadiene from a cracker's product stream. Here again, the isobutene content depends on the nature of the cracker feedstock.

Balance between local supply and demand will be tight, so Steel foresees a rising isobutene price profile. In contrast to the outlook for butadiene and isobutene, he envisages no shortage of *n*-butenes through the 1980s. The *n*-butenes are the main components of "raffinate-II," the stream remaining after removal of isobutene from raffinate-I. But any surplus *n*-butenes won't be wasted. Alkylate and polymer gasoline will provide major outlets. □

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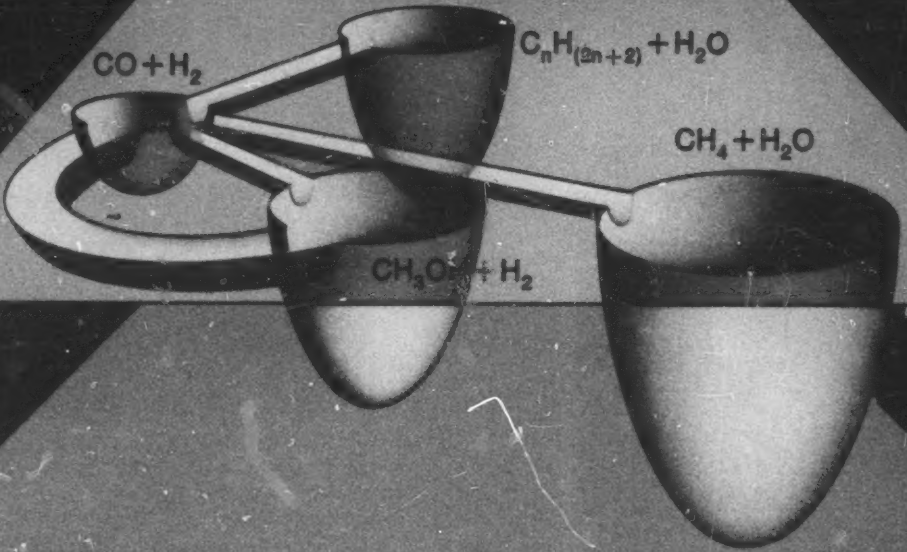
$CO + H_2$
$C_nH_{(2n+2)} + H_2O$
$CH_4 + H_2O$
$CH_3OH + H_2$

Industrial Catalysis

Selectivity by design Page 11

November 15, 1982
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Chemical & Engineering NEWS

Cover: Potential-energy surface for Fischer-Tropsch system indicating that a selective catalyst can provide a path to a particular reaction product

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News of the Week

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- ***More conflict arises over agent orange;*** *NRC recommends delaying a study of the herbicide's effects on American ground troops in Vietnam.* ***Page 7***
- ***International mobility of scientists and engineers*** *declined over the past decade, due in part to dwindling science budgets and increasing costs.* ***Page 7***
- ***Benzo[a]pyrene's potential to cause breast cancer*** *in humans may have been proven by research using a new method to culture pure mammary epithelial cells.* ***Page 8***
- ***Soviet actions against dissident scientists*** *being protested by leading Western scientists as well as by many university leaders and scientific societies.* ***Page 8***

News Focus

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International

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ACS News

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Third-quarter earnings drop is worst yet

Profits at major chemical firms plunged 37% and sales fell 9%; earnings also were down at petroleum and diversified companies

William J. Storck, C&EN
New York, and William F.
Fallwell, C&EN Washington

In every recession there is a quarter that must be the worst—a three-month period that makes observers sometimes wonder if the industry will ever recover. Chemical industry executives undoubtedly are hoping that the third quarter of 1982 was that sort of pit.

Unfortunately, the fourth quarter, seasonally weak even in good years, is not going well and likely will hand the industry another earnings setback. However, a fourth-quarter drop may be less severe, since profits fell fast in fourth-quarter 1981. At the moment, business is tilting only slightly further down, and some important product lines are trying an upward counterattack in prices.

Add to these price moves six months of highly encouraging trends in pace-setting financial markets such as stocks and bonds, and you get a consensus among industry spokesmen that recovery seems definitely in view in early 1983. Still, the universal word is caution on just how fast any recovery will proceed.

So for 1982 as a whole, it looks as if the basic chemical industry will have earnings down more than 30%, sales down about 7%, and profit margins on sales down to about 4.1%.

For the period companies have just reported, third-quarter earnings drops affected all types of U.S. chemical producers—basic chemical, diversified, and especially oil companies whose earnings from petrochemical operations were wiped out. Only a pickup in refining economics saved the oil companies' overall results.

For C&EN's core survey of 40 major basic chemical companies, earnings for the third quarter dropped 37% from last year. This, combined with the cumulative 34% drop through the first half, means that the year's earnings thus far are down 35%. At this rate, it would take a miracle to keep earnings from plunging more than a third for the whole year.

Chemical industry leaders for third-quarter . . .

Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1981		$ Millions	Rank 1981		Earnings as % of sales	Rank 1981
1	Dow Chemical	$2548.0	1	Allied	$81.0	3	Freeport-McMoRan	18.4%	1
2	Union Carbide	2164.1	2	Monsanto	71.0	5	Nalco Chemical	11.0	4
3	Allied	1514.0	5	Union Carbide	60.5	1	First Mississippi	10.2	2
4	Monsanto	1504.5	3	W. R. Grace	44.4	4	Lawter International	10.1	3
5	W. R. Grace	1441.9	4	PPG Industries	43.7	6	Petrolite	9.2	10
6	FMC	863.0	9	Dow Chemical	35.0	2	Great Lakes Chemical	8.0	5
7	American Cyanamid	861.2	7	Freeport-McMoRan	34.3	8	International Minerals	6.8	9
8	PPG Industries	840.0	8	Air Products	29.7	14	Loctite	6.8	8
9	B. F. Goodrich	795.4	10	FMC	29.0	9	Chemed	6.1	11
10	Celanese	714.0	6	American Cyanamid	27.1	6	Lubrizol	6.0	5

. . . and for first nine months 1982

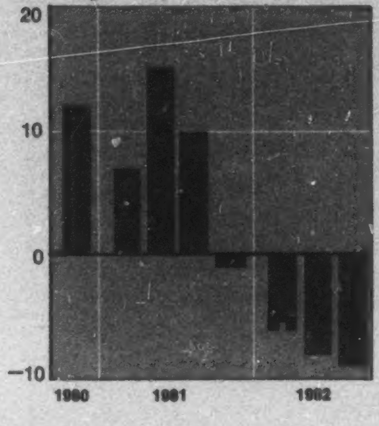
Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1981		$ Millions	Rank 1981		Earnings as % of sales	Rank 1981
1	Dow Chemical	$8057.0	1	Monsanto	$304.7	3	Freeport-McMoRan	15.0%	1
2	Union Carbide	6775.6	2	Union Carbide	269.5	1	Nalco Chemical	10.2	3
3	Monsanto	4859.6	3	Allied	226.0	4	Petrolite	9.8	8
4	Allied	4723.0	5	Dow Chemical	209.0	2	Stauffer Chemical	9.3	7
5	W. R. Grace	4535.3	4	W. R. Grace	200.4	5	Lawter International	9.0	5
6	FMC	2612.4	9	PPG Industries	113.5	6	Great Lakes Chemical	8.4	2
7	American Cyanamid	2607.8	7	Stauffer Chemical	113.4	9	Air Products	7.0	11
8	PPG Industries	2470.0	8	FMC	106.7	10	Chemed	6.9	9
9	Celanese	2352.0	6	American Cyanamid	90.3	7	Lubrizol	6.7	6
10	B. F. Goodrich	2300.0	10	Freeport-McMoRan	83.4	8	Liquid Air	6.4	12

[a] After taxes. Note: For 40 chemical companies listed on page 22.

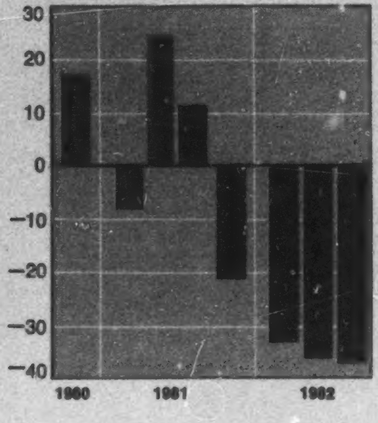
Chemical Industry Third-Quarter Results

- **Sales fell 9%**
- **Earnings plunged 37%**
- **Profitability fell to 3.5%**
- **Production sank 11%**
- **Prices dropped 0.4%**

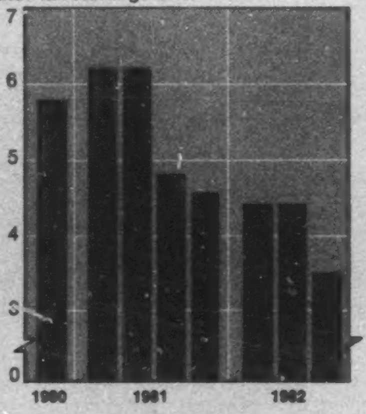
Sales
% change from year-earlier quarter



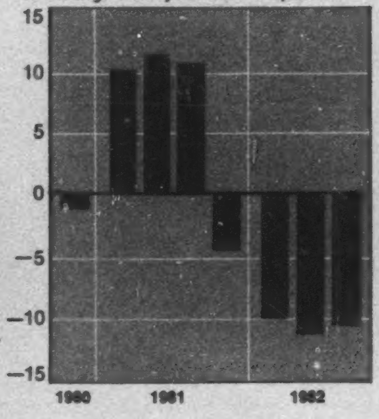
Earnings
% change from year-earlier quarter



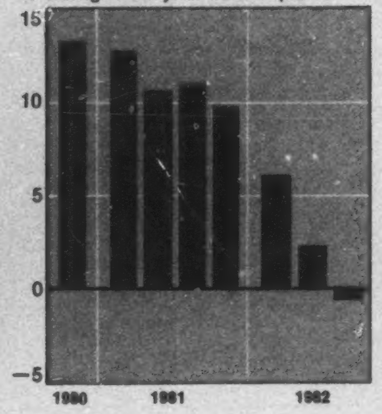
Profit margins
After-tax earnings as % of sales



Production
% change from year-earlier quarter

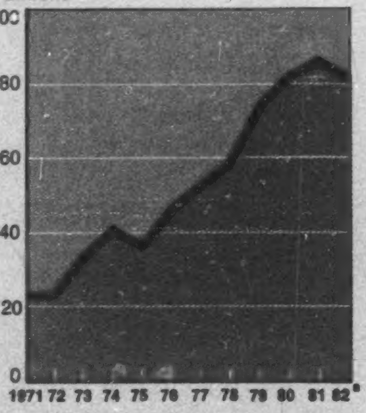


Prices
% change from year-earlier quarter

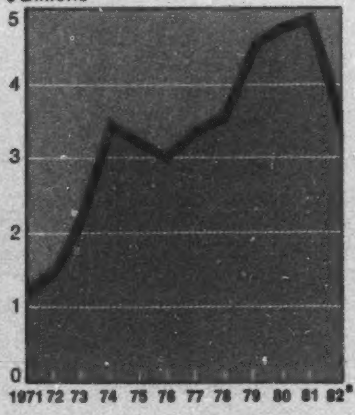


Sales in 1982 will fall about 7%, and earnings will drop more than 30%, sending profitability down to about 4.1%

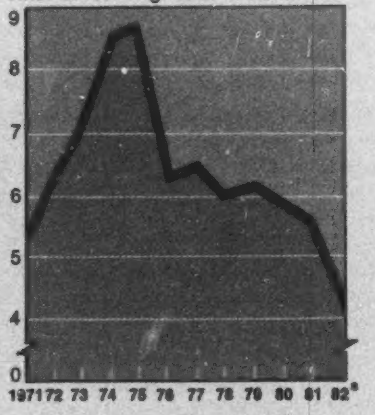
Annual sales
$ Billions



Annual earnings
$ Billions



Annual profit margins
After-tax earnings as % of sales



a C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on the combined performance of the 40 largest chemical makers listed on page 22.

Third-quarter chemical earnings at chemical companies fell 37% as profit margins plunged

	THIRD-QUARTER 1982						NINE-MONTHS 1982			
	Sales	Earnings	Change from 1981		Profit margin[a]		Sales	Earnings	Change from 1981	
	($ millions)		Sales	Earnings	1982	1981	($ millions)		Sales	Earnings
Dow Chemical[d]	$ 2,548.0	$ 35.0	−13%	−73%	1.4%	4.4%	$ 8,057.0	$ 209.0	−9%	−56%
Union Carbide[e]	2,164.1	60.5	−11	−61	2.8	6.4	6,775.6	269.5	−13	−47
Allied[f]	1,514.0	81.0	−2	1	5.4	5.2	4,723.0	226.0	0	−10
Monsanto[g]	1,504.5	71.0	−8	27	4.7	3.4	4,859.6	304.7	−10	−6
W. R. Grace[h]	1,441.9	44.4	−9	−31	3.1	4.0	4,535.3	200.4	−5	−19
FMC	863.0	29.0	2	−29	3.4	4.8	2,612.4	106.7	5	−13
American Cyanamid[i]	861.2	27.1	−8	−48	3.1	5.6	2,607.8	90.3	−4	−39
PPG Industries	840.0	43.7	−1	−16	5.2	6.2	2,470.0	113.5	−3	−34
B. F. Goodrich[j]	795.4	−0.1	−3	def	def	1.8	2,300.0	−3.5	4	def
Celanese	714.0	−18.0	−25	def	def	3.5	2,352.0	20.0	−18	−82
Hercules[k]	602.0	25.6	−13	−29	4.3	5.2	1,890.0	69.8	−9	−42
National Distillers	448.4	15.5	−7	−49	3.5	6.3	1,377.7	61.9	−9	−38
Rohm & Haas[l]	441.3	17.2	−1	−20	3.9	4.8	1,444.6	61.2	−2	−26
Olin	433.9	11.2	−11	−37	2.6	3.6	1,407.8	56.6	−10	−28
Air Products[m]	415.6	29.7	3	3	6.5	6.5	1,195.4	83.2	−1	−11
Ethyl	410.7	23.0	−8	8	5.6	4.7	1,231.0	68.0	−7	1
Williams Cos.	380.6	−0.3	−21	def	def	2.9	1,332.4	25.0	−14	−72
International Minerals	356.5	24.4	−12	−32	6.8	8.9	1,176.4	52.6	−19	−55
Witco Chemical[n]	331.8	8.6	2	−10	2.6	2.9	1,001.7	21.5	2	−22
Stauffer Chemical[o]	283.6	14.1	−17	−1	5.0	4.2	1,219.5	113.4	−10	−10
Pennwalt	232.4	7.3	−10	−46	3.1	5.3	732.8	24.5	−9	−38
Lubrizol	199.0	11.9	−10	−50	6.0	10.8	615.7	41.1	−9	−45
Reichhold Chemicals	197.4	1.1	−20	−71	0.6	1.6	630.2	8.2	−15	−47
Morton Thiokol[p]	193.5	14.5	1	—	7.5	—	652.3	41.4	5	—
Freeport-McMoRan	186.1	34.3	−8	−23	18.4	21.8	556.1	83.4	−13	−37
GAF[q]	179.2	8.8	1	def	4.9	def	482.1	−1.3	−9	def
Nalco Chemical	160.1	17.6	−5	−17	11.0	12.6	485.0	49.4	−1	−18
International Flavors[r]	—	—	—	—	—	10.1	—	—	—	—
Liquid Air	115.2	6.0	10	−16	5.2	6.8	339.0	21.6	5	−10
H. B. Fuller	79.6	2.5	−5	−34	3.1	4.6	235.2	6.6	−5	−36
Petrolite	73.6	6.8	−1	21	9.2	7.5	230.9	22.6	5	12
Chemed[s]	64.2	3.9	−1	−19	6.1	7.4	188.9	13.1	1	−15
Stepan Chemical	54.3	1.7	8	22	3.1	2.8	160.8	4.2	3	−6
Loctite	53.1	3.6	−3	−29	6.8	9.4	162.3	10.1	−3	6
Crompton & Knowles	52.3	0.6	−14	−61	1.2	2.7	162.3	2.7	−13	−54
First Mississippi	49.2	5.0	14	−27	10.2	15.8	163.0	9.7	−11	−25
Great Lakes Chemical	43.9	3.5	8	−21	8.0	10.8	126.7	10.7	15	−26
Essex Chemical[t]	40.3	1.5	−1	−36	3.7	5.6	125.2	5.5	−6	−4
Philip A. Hunt	29.4	1.0	7	−41	3.4	6.2	89.2	5.0	9	9
Lawter International	19.8	2.0	−7	−31	10.1	13.6	60.3	5.4	−8	−27
Total 20 largest companies	**$17,350.5**	**$542.6**	**−8.8%**	**−40.2%**	**3.1%**	**4.9%**	**$54,569.2**	**$2149.8**	**−7.5%**	**−35.2%**
Total 18 other companies[u]	**$ 1,829.1**	**$119.1**	**−7.0%**	**−20.2%**	**6.5%**	**7.6%**	**$ 5,545.7**	**$ 322.5**	**−6.5%**	**−30.0%**
GRAND TOTAL[u]	**$19,179.6**	**$661.7**	**−8.7%**	**−37.4%**	**3.5%**	**5.0%**	**$60,114.9**	**$2472.3**	**−7.4%**	**−34.6%**

a After-tax income as a percentage of sales. b Fully diluted before nonrecurring and extraordinary items. c As of Oct. 29. d Excludes $177 million extraordinary and nonrecurring gains in nine months 1982 and $20 million nonrecurring gain in nine months 1981. e Excludes $10 million nonrecurring gain in third quarter; third-quarter and nine-months 1981 figures are restated for accounting changes. f Excludes $38 million nonrecurring gain in third-quarter 1981. g Excludes $67.7 million nonrecurring gain in third-quarter 1981. h Excludes $33.7 million nonrecurring gain in third-quarter and nine-months 1981 and $85.1 million nonrecurring gain in nine-months 1982. i Excludes $2.9 million nonrecurring gain in third-quarter 1982. j Excludes nonrecurring gain of $8.5 million in third-quarter 1981, $4.4 million in nine-months 1982, and $30.8 million in nine-months 1981. k Excludes $6.2 million nonrecurring gain in third-quarter 1982. l Excludes

In a rare event, annual sales also are dropping, with a fresh decline of 9% in the third quarter. And profitability on sales is falling to its lowest level in decades, not much more than 4.0%.

So a miracle would serve just fine about now, but miracles may be in short supply. The problems grinding on the chemical industry all year are still there, even if their severity is no longer increasing.

Major markets remain depressed. The housing industry, though showing a few signs of upturn, is still in dire trouble. The automobile industry is in a shambles, and even when it begins to recover, it will be bucking imports. The farm economy is not good and could get worse. And fibers continue to battle rising textile imports, while a stronger U.S. dollar and weak foreign economies undermine exports.

		12-MONTH RUNNING DATA				STOCK MARKET DATA[c]							
Profit margin[a]		Change from 1981		Profit margin		Earnings per share[b]		Stock price			Price earnings ratio Oct. 29	Annual indicated dividend	Dividend yield, % of price
1982	1981	Sales	Earnings	1982	1981	3rd qtr	Recent 12 months	Oct. 29	Recent 12 months High	Low			
2.8%	5.4%	−11%	−55%	2.7%	5.3%	$0.18	$1.43	$25¾	$28½	$19⅝	18	$1.80	7.0%
4.0	6.5	−12	−36	4.4	6.1	0.88	5.95	54¼	58⅞	40⅛	9	3.40	6.3
4.8	5.3	4	−8	5.0	5.6	1.95	7.62	34¼	48⅜	28¾	4	2.40	7.0
6.3	6.0	−9	−2	5.8	5.2	1.79	9.14	77¼	84⅞	56⅝	8	4.00	5.2
4.4	5.2	−3	−19	4.5	5.4	0.91	6.04	39⅜	46½	28½	7	2.80	7.1
4.1	4.9	5	−6	4.3	4.9	0.81	4.23	31¾	35	23⅛	8	1.80	5.7
3.5	5.5	−1	−19	4.1	5.0	0.56	3.01	33¾	35⅜	24⅜	11	1.75	5.2
4.6	6.7	−2	−35	4.5	6.9	1.27	4.24	48⅛	50¼	29	11	2.36	4.9
def	1.9	−4	−61	0.9	2.3	−0.15	0.98	26¾	27¾	16⅝	27	1.56	5.8
0.9	3.8	−15	−63	1.7	4.0	−1.25	3.06	49⅛	62	41⅝	16	4.00	8.1
3.7	5.8	−6	−5	4.8	4.7	0.58	2.24	26¾	28¾	16⅞	12	1.32	4.9
4.5	6.6	−5	−26	5.4	7.0	0.41	2.91	25¼	26¾	18⅞	9	2.20	8.7
4.2	5.6	−2	−24	4.1	5.3	1.33	5.82	68⅞	71½	45½	12	2.80	4.1
4.0	5.1	−8	−23	3.8	4.5	0.48	2.99	23⅛	24½	15½	8	1.20	5.2
7.0	7.8	0	−9	7.3	8.0	1.03	4.03	32⅜	40¼	23⅝	8	0.80	2.5
5.5	5.0	−6	5	5.7	5.1	1.13	4.53	31½	31½	18⅛	7	1.50	4.8
2.2	6.7	−14	−81	1.4	6.4	0.11	1.17	17⅞	30⅝	12⅝	15	1.20	6.7
4.5	8.0	−18	−49	5.1	8.2	0.92	3.04	32⅞	36	23½	11	2.60	7.9
2.1	2.8	1	−5	2.6	2.8	0.91	3.46	26⅛	27	20⅝	8	1.80	6.9
9.3	9.3	−10	−10	8.6	8.6	0.31	3.13	24	25	17	8	1.44	6.0
3.3	4.9	−18	−26	3.1	3.5	0.70	2.02	34⅜	34⅞	21½	17	2.20	6.4
6.7	11.0	−10	1	9.5	8.5	0.31	1.51	19⅝	26¼	14¼	13	1.08	5.5
1.3	1.8	−13	−36	1.5	2.1	−0.05	0.89	13½	15⅜	10	15	0.48	3.6
6.3	—	—	—	6.1	—	—	—	49⅜	50	27¾	5	1.52	3.1
15.0	21.0	−7	−44	13.0	21.5	0.49	1.54	15¾	28⅛	12¼	10	0.60	3.8
def	0.4	−11	def	def	0.0	0.59	−0.93	12¼	15¼	8⅝	—	0.20	1.6
10.2	12.2	2	−12	10.7	12.3	0.44	2.69	28	29⅜	18	10	1.12	4.0
—	11.7	—	—	—	14.7	—	—	23⅞	27	17⅜	14	1.04	4.4
6.4	7.4	4	0	6.7	6.9	0.46	2.32	19¾	20¾	14½	9	1.60	8.1
2.8	4.2	2	−30	3.1	4.4	0.55	2.13	22⅝	26½	14¼	11	0.52	2.3
9.8	9.1	8	17	9.8	9.1	0.57	2.54	27½	37	19¾	11	1.00	3.6
6.9	8.2	3	−30	6.9	10.3	0.45	1.45	27	31	21⅝	19	1.25	4.6
2.6	3.4	7	5	2.9	2.9	0.48	1.70	12¾	20	9¼	8	0.56	4.4
6.2	5.7	−2	−6	6.6	6.8	0.37	1.42	29¼	30¾	18⅛	21	0.56	1.9
1.7	3.2	−12	−32	2.5	3.2	0.16	1.49	14⅜	18⅛	12⅛	10	1.04	7.2
6.0	7.1	−8	−39	6.1	9.2	0.25	0.77	9⅜	16⅞	6	12	0.24	2.6
8.4	13.1	15	−28	8.6	13.7	0.49	1.99	37⅜	45	24⅞	19	0.56	1.5
4.4	4.3	−4	−16	4.3	4.8	0.51	2.44	20½	20½	15⅞	8	0.80	3.9
5.6	5.6	8	def	3.6	def	0.18	0.73	11⅝	12¼	8⅝	16	0.40	3.4
9.0	11.2	−7	−24	9.9	12.1	0.17	0.69	11¼	12⅜	8⅝	16	0.72	6.4
3.9%	5.6%	−6.5%	−28.9%	4.2%	5.5								
5.8%	7.8%	−6.5%	−26.7%	5.7%	7.3%								
4.1%	5.8%	−6.5%	−28.6%	4.3%	5.6%								

$9.0 million nonrecurring charge in nine-months 1981. m Excludes $9.3 million nonrecurring charge in nine-months 1982. n Excludes $1.0 million nonrecurring charge in third-quarter 1982 and $0.6 million nonrecurring gain in nine-months 1982. o Includes extraordinary item. p Because merger of Morton and Thiokol was not yet complete, Thiokol's earnings were reported on an equity basis making comparisons with prior years meaningless. q Third-quarter 1982 excludes $7.0 million nonrecurring gain. r Not all data available at press time. s Excludes $5.3 million nonrecurring gain in third-quarter 1981. t Excludes $0.9 million nonrecurring gain in nine-months 1981. u Excludes results of Morton Thiokol for purposes of comparison. def = deficit.

As a result, chemical production continues its declines, causing capacity to muddle along at a 63% rate (C&EN, Oct. 11, page 12). And prices for chemicals and allied products, although stabilizing lately, are below their year-ago levels.

This combination is wrecking not only profits at major chemical companies, but also sales. For the first time since 1975, the only previous year in recent decades, sales for the full year for basic chemical companies will be down—probably 7% or more.

The sales and earnings drops in the third quarter were widespread. Of the 40 companies surveyed, earnings for 31, or almost 80%, declined from a year ago. Almost the same number, 29, had sales drops. Earnings' declines for three firms—B. F. Goodrich, Celanese, and Williams Cos.—resulted from deficits.

Total sales for 38 of the 40 com-

Sales and earnings continue down at many petroleum companies

	% chemical sales	THIRD-QUARTER 1982 Sales ($ millions)	Earnings ($ millions)	Change from 1981 Sales	Change from 1981 Earnings	Profit margin[a] 1982	Profit margin[a] 1981	NINE-MONTHS 1982 Sales ($ millions)	Earnings ($ millions)	Change from 1981 Sales
Exxon	7%	$25,331.0	$1070.0	−8%	0%	4.2%	3.9%	$77,477.0	$3195.0	−9%
Mobil	3	15,534.0	323.0	−7	−36	2.1	3.0	47,727.0	959.0	−5
Texaco[b]	3	11,800.0	411.0	−18	−30	3.5	4.1	36,300.0	1033.0	−19
Standard Oil of California	3	8,666.0	459.0	−24	−13	5.3	4.6	28,056.0	952.0	−19
Standard Oil (Ind.)[b]	8	7,676.0	608.0	−4	15	7.9	6.6	22,399.0	1460.0	−6
Gulf Oil[b]	8	7,538.0	204.0	1	−35	2.7	4.2	22,502.0	720.0	0
Atlantic Richfield	10	6,659.4	446.9	−4	3	6.7	6.2	19,895.4	1242.1	−6
Shell Oil	15	5,098.0	442.0	−9	−6	8.7	8.4	15,037.0	1166.0	−9
Phillips Petroleum	15	4,002.0	131.6	3	−32	3.3	4.9	11,845.0	460.4	−3
Sun Co.[b]	5	3,800.0	152.0	3	−28	4.0	5.7	11,800.0	386.0	2
Tenneco[b]	10	3,674.0	198.0	3	26	5.4	4.4	11,223.0	486.0	1
Standard Oil (Ohio)	3	3,175.0	487.3	−14	3	15.3	12.7	9,387.4	1420.0	−7
Getty Oil	2	3,073.0	178.1	−6	−13	5.8	6.3	9,275.9	493.4	−5
Union Oil[b]	11	2,771.7	212.8	−5	10	7.7	6.6	8,163.0	578.9	−3
Cities Service[b]	3	1,970.7	45.4	2	−42	2.3	4.1	5,933.9	97.1	1
El Paso[b]	15	954.8	26.8	−1	−32	2.8	4.1	2,845.2	66.2	2
Kerr-McGee[b]	14	913.5	56.8	−4	13	6.2	5.3	2,762.0	153.2	0
Internorth[b]	10	806.2	14.5	9	−23	1.8	2.5	2,980.5	143.6	14
American Petrofina	13	540.1	12.7	−12	−41	2.4	3.5	1,723.3	39.6	−13

a After-tax income as percentage of sales. b Excludes major nonrecurring gains or charges to earnings: Texaco—$108 million charge in the third-quarter 1982; Standard Oil (Ind.)—$49 million charge in third-quarter 1982 and $80 million gain in third-quarter 1981; Gulf Oil—$58 million charge in third-quarter 1982 and $97 million charge in nine-months 1982; Sun Co.—$135 million gain in second-quarter 1981; Tenneco—$73 million gain in second-quarter 1982; Union Oil—$24.4 million gain in second-quarter 1981; Cities Service—$21.4 million charge in:

Petrochemical profits disappeared in third quarter

The long night continues for chemical operations, chiefly petrochemicals, at U.S. oil and natural gas companies. Making up one sales dollar out of every four in U.S. chemicals—the biggest block outside the basic chemical industry—these operations as a group lost all profitability in the third quarter.

Third-quarter chemical earnings came to a slight combined loss at five leading oil companies reporting after-tax data. That's by far the worst decline yet in petrochemicals' extended private recession, which has run without letup, in terms of earnings drops, since third-quarter 1980.

It was a lucky oil or gas company that could use black ink for chemicals in the third quarter. Losses stud the list. At Shell Oil, which lost $15 million in chemicals in the third quarter, president John F. Bookout comments, "The improvement in chemicals we hoped for six months ago has not materialized. If anything, demand and prices continued to weaken during the summer."

This means that chemicals are running counter to a considerably improved performance in Shell's oil products segment (refining, transportation, and marketing). Record profits here helped Shell hold its overall profits drop to just 6% and keep its profit margin on sales at a very respectable 8.7%. Other oil companies echo Shell's report of a pickup in refining operations, and some sport a similar improved overall profit margin.

So chemicals stand out worse than ever in oil companies' results. In the worst case, Gulf Oil gave up on several of its specialty chemical units (mainly at acquired Millmaster Onyx) and wrote them off for more than $100 million (pretax). This move gave Gulf an operating loss of $144 million pretax on its U.S. chemical operations in the third quarter and $194 million for the nine months. In 1981, these chemicals were marginally profitable in the third quarter and lost $22 million in the first nine months.

The largest petrochemical producers barely made money in the third quarter. At Exxon, the largest producer, chemical profits sank 75% from a year ago to just $16 million on sales (including intracompany transfers) of $1.71 billion. Sales in dollars fell 14% in the third quarter and 15% in the first nine months from 1981. In volume, nine-month sales were off 10% in the U.S. and 7% abroad.

Smaller chemical operations had a rougher time. Mobil's $518 million in chemical sales eked out $3 million in profits in the third quarter. Standard Oil (Ind.) about broke even on its chemical sales of $585 million.

AFTER-TAX EARNINGS

$ Millions	Third quarter 1982	1981	% change	Nine months 1982	1981	% change
Exxon	$16.0	$ 65.0	−75%	$ 83.0	$222.0	−63%
Mobil	3.0	17.0	−82	33.0	70.0	−53
Shell Oil	−15.0	14.0	def	1.0	35.0	−97
Standard Oil (Ind.)	0.0	19.0	−100	83.0[a]	110.0	−25
Texaco	−5.0	13.0	def	15.0	62.0	−76
TOTAL	$−1.0	$128.0	def	$215.0	$499.0	−57%

a Includes nonrecurring gain of $19 million. Def = deficit.

NINE-MONTHS 1982			STOCK MARKET DATA							
Change from 1981	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio Oct. 29	Annual indicated dividend	Dividend yield, % of price
						Recent 12 months				
Earnings	1982	1981	3rd qtr	Recent 12 months	Oct. 29	High	Low			
−29%	4.1%	5.3%	$1.23	$4.90	$29⅝	$33⅛	$24⅞	6	$3.00	10.1%
−48	2.0	3.7	0.78	3.68	25	28⅝	19½	7	2.00	8.0
−40	3.0	4.0	1.57	6.11	30⅝	35⅛	26	5	3.00	9.8
−47	3.4	5.3	1.34	4.45	30¼	46	23½	7	2.40	7.9
0	6.5	6.1	2.09	6.29	41⅛	55¾	33½	7	2.80	6.8
−23	3.2	4.1	1.15	5.34	28½	38½	24¼	5	2.80	9.8
3	6.2	5.7	1.76	6.77	42½	50⅜	32¼	6	2.40	5.6
−6	7.8	7.5	1.43	5.27	38¼	46⅞	27⅛	7	1.80	4.7
−34	3.9	5.7	0.86	4.25	31¼	45⅞	23½	7	2.20	7.0
−22	3.3	5.4	1.25	4.36	32½	48¾	26¾	7	2.30	7.1
−12	4.3	5.0	1.38	5.31	33⅛	34⅞	22⅞	6	2.72	8.2
−3	15.1	14.5	1.97	7.68	36⅝	46¼	26½	5	2.60	7.1
−23	5.3	6.5	2.23	8.74	56	70½	41¼	6	2.60	4.6
9	7.1	6.3	1.22	4.69	27⅞	42⅝	21¼	6	1.00	3.6
−57	1.6	3.8	0.61	2.77	48¼	56⅜	23¾	17	1.60	3.3
−39	2.3	3.9	0.54	2.16	17	28⅛	13⅝	8	1.48	8.7
6	5.5	5.3	1.08	4.19	30⅞	42¼	22½	7	1.10	3.6
−18	4.8	6.7	0.32	4.73	28⅛	32¼	21	6	2.12	7.5
−31	2.3	2.9	1.17	5.24	55¾	63⅜	41½	11	3.20	5.7

third-quarter 1982 and $45.5 million gain in nine-months 1982; El Paso—$5.9 million gain in third-quarter 1982; Kerr-McGee—$17.0 million charge in second-quarter 1982; Internorth—$9.5 million gain in third-quarter 1981.

panies, that had reported by press time and had comparable year-to-year data, in the third quarter dropped 8.7% to $19.2 billion from the same period of 1981. (The year-to-year comparisons do not include Morton Thiokol. Earnings at this company are not comparable to those of a year ago. The acquisition of Thiokol was as yet incomplete at the end of the third quarter, and earnings from Thiokol are reported on an equity basis. Since prior years have not been restated, comparison of the results between the two years is not yet meaningful.)

Combined earnings for the quarter took a big drop to $662 million, down 37% from last year's level. This is the biggest drop in earnings in the current recession, beating the second quarter's year-to-year decline of 36%.

As in the past, the larger, more commodity-oriented chemical companies performed worse than did the smaller firms in the third quarter. Among the 20 larger firms, combined sales dropped 8.8% from third-quarter 1981 to $17.4 billion. Earnings among the top group fell 40.2% to $543 million.

Earnings among this group were dragged down by some huge drops at some larger firms. Dow Chemical, the largest company on the list, posted an earnings decrease of 73% from last year's third quarter to $35.0 million. Union Carbide's earnings fell 61% to $61 million. (The third-quarter 1981 figure for Union Carbide has been restated to reflect an accounting change, making the two years comparable. Carbide's actual third-quarter 1981 earnings were considerably lower, $138 million.)

Of the 20 larger companies surveyed, seven, including the three with losses, recorded earnings drops greater than the 40.2% average. Without these seven companies, earnings among the remaining 13 firms were down just 11.6% from a year ago.

There were not such big differences in sales, however. Except for a couple of big declines—25% at Celanese and 21% at Williams Cos.—most sales declines were close to the average. Countering the large declines, sales gained a little at three companies—FMC, Air Products, and Witco Chemical.

Profit margins (earnings as a percentage of sales) at the 20 larger firms continued their slide in the third quarter. The average profit margin for the group was 3.1%, compared to 4.8% in third-quarter 1981.

For the first nine months of 1982, the profit margin decline is not so bad. But it is bad enough to foretell the lowest full-year profitability since World War II. Specifically, for the first nine months, earnings among the 38 companies used to figure the average declined 35% to $2.47 billion from the first three quarters of 1981. Sales for the group dropped 7.4% to $60.1 billion. As a result, profit margins for the chemical companies fell to 4.1% from 5.8% in the same period of 1981.

Once again the larger firms had the larger fall in the year's first three quarters. Total earnings of the 20 bigger companies fell an average of 35% from the first nine months of 1981 to $2.15 billion. Sales dropped 7.5% to $54.6 billion. As a result the average profit margin for the group dropped to 3.9% from 5.6% in the first three quarters last year.

Among the smaller firms, combined earnings dropped an average of 30% during the first three quarters to $323 million. Total sales for the group fell 6.5% to $5.55 billion, driving profit margins down to 5.8% from 7.8% in the first nine months of 1981.

The third quarter spared hardly any major product group. A good example comes from Celanese, where

Earnings damage was heavy at many diversified chemical producers

		THIRD-QUARTER 1982						NINE-MONTHS 1982		
	% chemical sales	Sales ($ millions)	Earnings ($ millions)	Change from 1981 Sales	Change from 1981 Earnings	Profit margin[a] 1982	Profit margin[a] 1981	Sales ($ millions)	Earnings ($ millions)	Change from 1981 Sales
Du Pont	31%	$8202.0	$195.0	−1%	−29%	2.4%	3.3%	$24,963.0	$ 692.0	2%
General Electric	4	6390.0	451.0	−4	11	7.1	6.1	19,040.0	1293.0	−3
U.S. Steel[b]	10	4522.8	−82.4	30	def	def	15.5	14,625.6	1.8	37
Procter & Gamble	4	3201.0	257.0	6	15	8.0	7.4	9,274.0	620.0	6
Eastman Kodak	19	2542.1	303.9	0	−9	12.0	13.1	7,220.2	733.5	−1
Dart & Kraft[c]	11	2496.3	106.8	−3	16	4.3	3.6	7,433.4	304.8	−2
Beatrice Foods[c]	5	2334.8	84.3	1	2	3.6	3.6	6,840.0	229.6	1
Goodyear Tire & Rubber[b,c]	12	2160.0	89.0	−6	29	4.1	3.0	6,600.0	197.9	−4
3M	15	1691.0	169.2	0	−1	10.0	10.2	5,044.0	480.3	2
Georgia-Pacific[b,c]	14	1422.0	−1.0	1	def	def	2.2	4,036.0	95.0	−4
Aluminum Co. of America[c]	11	1145.2	−11.6	−11	def	def	5.6	3,590.5	27.4	−8
Borden[c]	32	1058.1	43.0	−3	−5	4.1	4.1	3,025.3	92.3	−10
Pfizer	14	909.6	71.5	11	23	7.9	7.1	2,593.3	240.3	7
Martin Marietta	14	892.0	38.0	7	−37	4.3	7.2	2,586.2	94.0	6
Borg-Warner	24	809.3	36.1	5	−15	4.5	5.5	2,390.6	119.1	2
Esmark	18	779.1	20.8	−4	−24	2.7	3.4	2,318.9	62.5	2
Diamond Shamrock[c]	34	773.2	42.3	−6	−22	5.5	6.6	2,422.0	103.3	−3
Merck	23	753.4	94.5	8	10	12.5	12.3	2,271.6	315.6	5
Kaiser Aluminum[b]	17	696.3	63.3	−11	414	9.1	1.6	2,245.0	8.4	−10
Eli Lilly[c]	18	670.9	98.7	8	14	14.7	13.9	2,242.3	312.3	9
Engelhard[c]	11	533.2	17.1	6	−4	3.2	3.5	1,416.5	47.6	−14
General Tire[c]	19	509.4	29.0	−10	−2	5.7	5.2	1,551.7	54.7	−5
NL Industries[c]	23	500.4	34.0	−17	−61	6.8	13.5	1,798.1	200.6	0
Koppers	34	479.4	19.1	−11	−24	4.0	4.7	1,278.1	16.0	−15
Uniroyal[c]	28	471.2	4.3	−12	−65	0.9	2.3	1,497.3	13.6	−12
Northwest Industries	6	451.4	6.7	−45	−90	1.5	7.8	1,917.3	178.0	−17
Upjohn	17	430.0	20.1	−4	−41	4.7	7.6	1,366.1	101.4	−5
Emhart	16	400.8	17.7	0	−19	4.4	5.5	1,309.5	56.0	2
Tyler	36	225.0	4.3	6	−66	1.9	5.9	654.0	7.7	21
Vulcan Materials	34	198.3	18.0	−7	−25	9.1	11.2	550.3	46.5	−6

a After-tax income as percentage of sales. b Earnings include major nonrecurring items. c Excludes major nonrecurring gains or charges in earnings: Dart & Kraft—$75.8 million net charge in third-quarter 1982, $11.6 million net gain in third-quarter 1981, $71.6 million net charge in nine-months 1982, and $59.5 million net gain in nine-months 1981; Beatrice Foods—$31.9 million gain in second-quarter 1982 (first fiscal quarter 1983) and $45.1 million gain in third-quarter 1981 (second fiscal quarter 1982); Goodyear—$17.2 million gain in second-quarter 1982; Georgia-Pacific—$27.0 million gain in third-quarter 1982 and $130 million gain in first-quarter 1982; Aluminum Co. of America—$2.8 million charge in third-quarter 1982, $19.9

every business segment turned down and all but two showed losses. In the third quarter in domestic businesses, the company's plastics and specialties operations turned in a net loss of 27 cents a share, compared with net income of 29 cents a share in the same period last year. The chemicals group lost 12 cents a share compared to earnings of 74 cents a share last year. Its fibers operation was the only one to show a profit in the U.S., but even here net income dropped to 28 cents a share from $1.00 per share in the third quarter last year. Third-quarter 1982 profits all came in cellulosics, which earned 29 cents a share.

The profit in Celanese's fibers, however, was more than offset by losses in the company's overseas fibers operations. Here the red ink ran to 80 cents a share, compared with a loss of 26 cents a share in third-quarter 1981. Overseas plastics and specialties showed a profit of 6 cents a share, down slightly from last year's 7 cents a share.

There are a few signs that things may be getting a little better in plastics, if for no other reason than the effects of cost cutting and shutting down unprofitable operations.

At Monsanto, operating (pretax) profit for plastics and resins increased to $12 million in the third quarter from a loss of $2.6 million in the same period last year. Sales of plastics and resins at the company, however, dropped to $307 million, a 10.5% decline from third-quarter 1981.

At Allied Corp., income from fibers and plastics increased 19% in the third quarter to $32 million. But sales of fibers and plastics on a year-to-year basis fell 5.2% to $272 million.

One possible explanation for the increasing profits on sales declines comes from Hercules, which suggests that break-even rates at chemical plants are declining. Alexander F. Giacco, chief executive officer, says, "As we move into the fourth quarter, we see no evidence that the recession is ending. However, manufacturing efficiencies have improved to the extent that our break-even point is at about the 55% level."

Giacco is not the only chemical industry executive who does not yet see the end of the recession. Celanese chairman John D. Macomber says, "The demand for Celanese products is closely linked to sales of autos, housing, energy, and apparel. Although we have not yet had any real upturn in any of these sectors of the U.S. economy, we expect these industries and our own businesses to recover gradually in 1983."

NINE-MONTHS 1982					STOCK MARKET DATA					
Change from 1981			Earnings per share		Stock price			Price-earnings ratio	Annual indicated dividend	Dividend yield, % of price
Earnings	Profit margin[a] 1982	Profit margin[a] 1981	3rd qtr	Recent 12 months	Oct. 29	Recent 12 months High	Recent 12 months Low	Oct. 29		
−17%	2.8%	3.4%	$0.82	$5.20	$ 38½	$41¾	$30	7	$2.40	6.2%
8	6.8	6.1	1.99	7.69	85⅞	86¾	53⅛	11	3.40	4.0
−100	0.0	9.2	−0.88	1.05	18⅞	32¾	16	18	1.00	5.3
15	6.7	6.1	3.10	9.79	106⅛	115¾	73	11	4.20	4.0
−15	10.2	11.9	1.87	6.79	87⅜	98⅛	63¼	13	3.00	3.4
10	4.1	3.6	1.95	6.97	66¾	68⅞	48	10	3.60	5.4
0	3.4	3.4	0.76	2.82	23⅛	24½	16¾	8	1.50	6.5
−8	3.0	3.1	1.20	3.08	29⅜	30⅜	16	10	1.40	4.8
−6	9.5	10.4	1.44	5.46	72¾	76⅝	48	13	3.20	4.4
−31	2.4	3.3	0.89	0.99	20⅜	25	13¼	21	0.60	2.9
−89	0.8	6.5	−0.16	0.72	27¾	31	21⅞	39	1.20	4.3
−21	3.1	3.5	1.47	4.50	39⅞	40⅜	26¾	9	2.22	5.6
21	9.3	8.1	0.91	4.0[illegible]	71¼	80⅝	44⅝	17	1.84	2.6
−42	3.6	6.6	1.14	3.79	40½	47⅛	22¼	11	1.92	4.7
0	5.0	5.1	0.85	4.02	33⅜	36¼	22	8	1.52	4.6
−13	2.7	3.2	1.63	6.93	65½	66¾	38¾	9	1.84	2.8
−39	4.3	6.8	0.66	2.60	22¾	29¾	16½	9	1.76	7.7
3	13.9	14.1	1.28	5.51	80½	88½	64	15	2.80	3.5
−94	0.4	5.9	1.46	−0.20	13⅝	17	11½	def	0.60	4.4
8	13.9	13.9	1.30	5.46	58⅜	65¼	45⅛	11	2.60	4.5
−11	3.4	3.3	0.64	2.45	28¾	30	17¾	12	0.56	1.9
11	3.5	3.0	1.22	3.04	26⅝	28¼	17⅞	9	1.50	5.6
−8	11.2	12.2	0.53	4.41	17⅝	45⅞	14¼	4	1.00	5.7
−57	1.3	2.5	0.61	0.78	14⅞	18⅜	11¼	19	1.40	9.4
−73	0.9	3.0	0.12	0.30	9¼	9⅞	5⅞	31	0	0
3	9.3	7.5	0.40	11.18	40½	80½	32½	4	4.40	10.9
−25	7.4	9.4	0.66	4.89	50⅝	59⅜	38	10	2.28	4.5
13	4.3	3.9	1.43	6.40	37¾	39¼	27¾	6	2.40	6.4
−70	1.2	4.7	0.45	1.02	21	23⅞	12⅛	21	0.60	2.9
−23	8.5	10.3	1.56	5.57	48	55	38¾	9	2.44	5.1

million gain in first-quarter 1982, and $9.5 million gain in third-quarter 1981; Borden—$2.9 million gain in third-quarter 1982, $10.4 million gain in second-quarter 1982, and $17.6 million gain in first-quarter 1982; Diamond Shamrock—$35.5 million gain in first-quarter 1982; Eli Lilly—$15.2 million charge in third-quarter 1982; Engelhard—$5.2 million charge in second-quarter 1981; General Tire—$2.6 million charge in third-quarter 1982, $4.9 million gain in second-quarter 1982, $30.8 million charge in second-quarter 1982, and $4.4 million charge in first-quarter 1982; NL Industries—$16.6 million charge in third-quarter 1982; Uniroyal—$18.0 million gain in first-quarter 1982. def = deficit.

Gradual recovery, when recovery comes, is the accepted thesis. Dow Chemical president and chief executive officer Paul F. Oreffice says, "The grim economic facts of life persist, and no meaningful signs of recovery are apparent. September rebounded from the traditional weak summer period, but even this gain was not as seasonally expected." Oreffice continues, "Economic conditions are ripe for a business improvement considering the declining trend of inflation and interest rates. However, we need a shift in consumer confidence to spur spending. I don't believe this change will occur overnight; . . . any economic recovery will be gradual."

From Du Pont, whose weak chemical operations have been largely balanced by improvements at Conoco, chairman Edward G. Jefferson concurs on the current state of business. "Although there are still no clear signs of recovery, we believe the recession has bottomed out for most of our traditional businesses. We are continuing our cost-reduction efforts, including a voluntary termination incentive program at our corporate headquarters that will result in a 7% reduction in the professional and managerial staff in the fourth quarter. We anticipate moderate recovery next year in chemical industry volume, and the energy segments are expected to show continued good performance."

A few executives exude a bit more on the coming year. At Goodyear, chairman Charles J. Pilliod Jr. forecasts, "Once the pentup demand is triggered in such interest-sensitive markets as autos, housing, and construction, we can look forward to renewed economic growth, an improved employment picture, and a healthier future both in the U.S. and abroad."

The path to a smoother future, however, has an immediate rocky stretch to negotiate. The chemical industry still has to get through the fourth quarter. To judge from the current market lethargy and the extraordinary pace of one-shot accounting moves such as writeoffs and divestments this year, a lot of bad news may be just ahead. For example, well-managed Vulcan Materials already has warned that its fourth-quarter earnings are expected down more than half from fourth-quarter 1981 after a 25% drop in the third quarter. The company's chemicals could account for more than half the pretax fourth-quarter earnings drop. If Vulcan has such prospects, more-vulnerable firms could too. □

Canadian chemical firms suffer heavy losses

For second quarter in row, combined profits of five major chemical companies were written in red ink; C-I-L was only one to escape

Canadian chemical companies took a financial beating in the third quarter. With sales down on a volume basis, with prices down, and with raw material and operating costs up, perhaps the results were inevitable. But no one suspected that they would be as bad as they were.

The combined results of five major Canadian chemical companies charted by C&EN tell the story in unmistakable terms. The companies are C-I-L, Celanese Canada, Du Pont Canada, Polysar, and Union Carbide Canada.

The combined sales of these companies in the third quarter were just over $1 billion (Canadian dollars used throughout this article), 11.6% lower than they were in the third quarter of 1981. But in the third quarter of 1981, these five companies enjoyed a combined profit of $25.6 million. This year, they lost $24.1 million in the third quarter.

This is the second quarter in a row in which their combined results were written in red ink. In the second quarter, they recorded a loss, but it amounted to only $4.3 million.

The only one of the five major chemical companies to escape the red ink was C-I-L. And it barely made it. Its third-quarter sales were down 13% from last year, but profits plunged 95% to only $600,000.

The company's diverse product line has always been credited with keeping C-I-L's head above water when other companies are floundering. But this time, president and chief executive officer C. H. (Chuck) Hantho says that a severe drop in demand hit across all product lines.

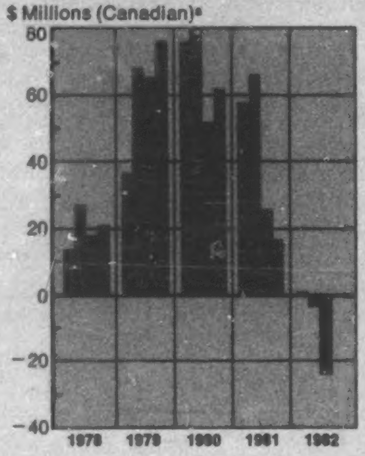
C-I-L's major customers in resource industries have been hard-hit by the recession. Many scheduled summer shutdowns were extended to and through the third quarter. The construction industry is operating at low levels and Canada's agricultural sector remains depressed.

Hardest hit of the five major chemical companies was Union Carbide Canada. Compared to the third quarter of 1981, this year's third-quarter sales were down 17.2% (to $168 million), the largest percentage drop of the five firms. To make matters worse, Carbide Canada lost $9.1 million in the third quarter, more than any of the five companies. Even Polysar, with sales 83% higher than Carbide Canada's, lost only $7 million in the third quarter.

Carbide Canada puts much of the blame for its performance squarely on government energy policies that have sharply boosted petrochemical feedstock costs. Meanwhile, the company has had little or no opportunity to recover those costs through higher prices.

Company chairman John S. Dewar notes that the decline in sales was all volume. Prices, he adds, remained unchanged, but costs increased 11%. Petrochemical feedstock costs alone have risen 15% so far this year in Canada, says Dewar, and they have declined as much as 30% in the U.S. This handicap, in the face of severely depressed petrochemical markets, both at home and abroad, helped to generate Carbide Canada's losses.

Combined earnings dove in the third quarter



a After-tax earnings of five largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont Canada, Polysar, and Union Carbide Canada.

Canadian chemical companies ache in the pocketbook

	NINE-MONTHS 1982					
$ Millions (Canadian)	Net sales	Change from 1981	Net income[a]	Change from 1981	Profit margin[b] 1982	Profit margin[b] 1981
C-I-L Inc.	$ 826.8	−6.3%	$17.3	−61.6%	2.1%	5.1%
Celanese Canada	230.8	−16.3	−5.9	def	def	6.3
Du Pont Canada	748.4	−14.2	−6.9	def	def	4.1
Polysar Ltd.	1012.6	0.1	−17.3	def	def	1.8
Union Carbide Canada	524.7	−15.8	−14.9	def	def	5.4
TOTAL	$3343.3	−8.8%	−$27.7	def	def	4.1%

a Net income from continuing operations, excluding extraordinary gains or losses. b Net income as a percentage of sales. def = deficit.

Du Pont Canada, whose sales and earnings were down in the third quarter, points to a tighter and tougher international market as part of the reason. The company's export sales were down 17%, reflecting not only lower overseas demand, but a stronger Canadian dollar against several major foreign currencies.

If there is any optimism to be found among company statements, it is by Celanese Canada. Noting that the third quarter is traditionally the weakest for the company, president and chief executive officer Ernest H. Drew says that the decline this year was not as severe as expected. He detects a significant improvement in September over July and August.

Other executives admit to seeing modest signs of economic recovery in Canada. But most think that the fourth quarter also will be a poor one.

Earl Anderson, New York

Biomaterials poised for major advances

Conference held by National Institutes of Health surveys status of field, proposes ways to help it achieve its potential in therapeutics

Richard J. Seltzer
C&EN, Washington

Suppose one asked an average television viewer what pops into mind when he or she hears the word "biomaterials"—substances used to replace, augment, or treat parts of the body? "The Bionic Man," "The $6 Million Man," or "The Bionic Woman" would be the response, more likely than not. How could a viewer not be intrigued and impressed by the concept of superhuman capacities created by replacement of body parts with synthetic ones—at a cost of $6 million for the bionic man?

Science fiction is far ahead of science in this case, as in so many others. But even without such heroics, progress in biomaterials has been dramatic in recent years. Indeed, says Pierre M. Galletti, vice president and professor of biology and medicine at Brown University, biomaterials "underlie what I consider the major revolution in therapeutics and in medicine in the second half of the 20th century." Biomaterials are already being used on "an extremely large scale," resulting in greatly improved patient care, he points out.

Yet, the emerging technology of biomaterials is only in its infancy, and its uses and potential uses are, by and large, not appreciated by the medical world and the public, Galletti believes. Significant improvements are needed in basic materials for current uses, and to enable preparation of more sophisticated medical devices to perform more complex tasks. And there is a whole host of questions surrounding biomaterials—technological, scientific, medical, economic, regulatory, legal, and social—that need to be addressed.

To bring the best available thinking to bear on these questions and to try to move the whole field forward, the National Institutes of Health earlier this month convened a consensus development conference in Bethesda, Md., on clinical applications of biomaterials. Bringing together some 350 physicians, dentists, polymer scientists, surface chemists, biochemists, materials scientists, metallurgists, chemical and biomedical engineers, mechanical engineers, microbiologists, business executives, lawyers, government officials, and consumers, the three-day conference was sponsored by the Biomedical Engineering & Instrumentation Branch of NIH's Division of Research Services. About 40% of the participants were from industry and 60% from the medical world, academia, and government.

C&EN staff photo

Galletti: major revolution in medicine

Biomaterials already used on vast scale in U.S.

Number applications per year

Cardiovascular implants	
Heart valves	30,000
Pacemakers	100,000
Vascular grafts	50,000–150,000
Dental implants	10,000–20,000
Plastic and reconstructive implants	
Breast prostheses	100,000
Cosmetic	78,000
After mastectomy	22,000
Nose, chin, other prostheses	10,000
Penile prostheses	5,000
Ophthalmic implants	
Lenses	250,000
Retinal surgery	25,000–50,000
Other prostheses	7,000–8,000
Orthopedic prostheses	
Hips	110,000
Knees	65,000
Shoulders, finger joints, other areas	50,000
Neurosurgical implants	
Ventricular shunts	21,500
Extracorporeal devices	
Oxygenators	196,000
For coronary bypass procedures	150,000
Renal dialyzers	6,200,000

Source: Collected by Arthur C. Beall Jr. of Baylor College of Medicine from multiple sources and his own estimates

Galletti chaired a consensus development panel of 16 members from a variety of backgrounds—including industrial and academic research on materials, incorporation of materials into medical devices, product development, quality control, marketing of medical devices, clinical use, receipt of medical devices as a consumer, and legal representation regarding medical devices. The panel focused on five key questions:

- How safe and effective are biomaterials currently in clinical use?
- How well can we predict biological performance of materials in the human body: host response, biomaterials response?
- What results of ongoing research in materials science would be potentially applicable to clinical care?
- Are the ways for introducing biomaterials into medical use responsive to current clinical needs? Which elements in the process are amenable to improvements?
- What are the areas of greatest clinical need for new biomaterials?

Consensus conferences assess medical technologies

Are some widely used medical technologies unsafe or ineffective? Are there other, less widely used technologies that are safe and effective and should be used more? How can the scientific community reach generally accepted answers to questions of technology assessment? And how can the scientific community improve translation of the results of biomedical research into medical practice?

Concerned about these questions and the lack of any formal mechanism to deal with them, the National Institutes of Health in 1977 started a program of consensus development conferences. These conferences—such as one held earlier this month on clinical applications of biomaterials—bring together research scientists, practicing physicians, consumers, and others for three days of intensive discussions focusing on a device, drug, or medical, surgical, or dental procedure that may be either new or already in general use.

The central element in the consensus process is a panel that includes a wide range of scientific and medical experts in fields relevant to the technology—including lawyers and other specialists where legal, social, or economic considerations are involved. (No federal officials serve on the panels.) The panel focuses on a specific set of questions regarding the technology. It listens to a series of lectures from experts, and to discussion and suggestions from the audience, since the conferences are open to all points of view.

The panel then seeks to reach a consensus among its members, and to issue a written report containing recommendations framed around the original questions and representing the best current thinking on the subject. The audience may suggest changes in the draft consensus report before it becomes final.

So far, 34 consensus development conferences have been held. They have covered such topics as breast cancer screening, estrogen use and postmenopausal women, adjuvant chemotherapy of breast cancer, carcinoembryonic antigen as a cancer marker, and computed tomographic scanning of the brain.

In some instances, the reports identify safe and useful new medical technologies and make a wider audience aware of their potential. In other cases, they find that a technology has not been validated adequately or point out problems a technology may cause, even recommending against using a technology under certain conditions. The consensus reports are published by the Government Printing Office and are disseminated to scientists, physicians, the public, and the media in the U.S. and abroad.

Speakers at the conference presented several definitions of biomaterials, but the consensus statement adopted by the panel defines biomaterials as "any substance (not a drug) or combination of substances, synthetic or natural in origin, which can be used for any period of time, as a whole or as a part of a system which treats, augments, or replaces any tissue, organ, or function of the body." This definition excludes some things, such as organ transplants. However, it is so broad that it embraces hearing aids, eyeglasses, renal dialysis machines, or, indeed, intravenous needles. Nevertheless, the bulk of the conference's attention focused on implants and prostheses used for long periods of time in the body.

Since the early 1950s, devices made with biomaterials have been introduced into the human body at an ever-increasing rate. Initially, use focused on life-threatening situations, but it since has expanded to treat or support a wide range of bodily functions for rehabilitation, comfort, convenience, and esthetics.

Similarly, "implant medicine" originally was viewed as a therapeutic approach in end-stage disease. However, it is now moving in the direction of restoration of chronically damaged structures, and some day may be able to carry out preventive maintenance in early stages of disease.

It is difficult to put exact figures on the magnitude of current use, but the consensus report says that several million biomaterial implants probably occur each year in the U.S. alone. Arthur C. Beall Jr. of Baylor College of Medicine cites estimates of some 100,000 pacemaker implants, 100,000 breast prostheses, and 110,000 hip prostheses.

In general, the consensus report finds currently used biomaterials safe and effective, with some variations. Little difficulty occurs from local tissue reaction or systemic toxicity. Some reports of immune responses are stimulating efforts to find less sensitizing materials. No apparent evidence exists of carcinogenic response. Few of these factors have been evaluated over extended periods of time, however, and the report recommends increased study to establish long-term safety.

As to the devices in which biomaterials are used, they are generally safe and effective, although significant improvements can be made. For example, hip replacements are much more successful than prostheses for other joints.

However, biological performance of materials in the body in terms of host response and biomaterials response can't be predicted very well at present. Researchers are only starting to study the science involved, and application has been largely empirical. Fundamental knowledge is limited on host responses and the effects of host tissues on materials. Surface and bulk properties may differ for a biomaterial, yielding variations in host and material responses. And biomechanical data is lacking for living tissues.

The consensus report notes that there is "a definite gap" between progress in materials science research and use of materials in biomedical applications. "The field of biomaterials is first and foremost a materials science," the report says. To date, notes Richard E. Clark of Washington University, St. Louis, practically no material used in an implantable device has been designed from the molecule up to meet specific long-term, in vivo conditions. Instead, most of the biomaterials have been off-the-shelf materials developed for nonmedical uses. And even there, says Galletti, only a handful of materials has been exploited for clinical use, and many others should be looked at.

The report points to several areas where materials science is mature enough to enable scientists to design specific biomaterials to provide improved host and biomaterial response to medical devices. In particular, Galletti says polymer chemistry, which he calls "the basic science of biomaterials," is on the verge of some very significant conceptual advances. Much as structure-activity relationships were developed for drugs a generation ago, scientists are now in a position to anticipate biological activities from a knowledge of the chemical structures of several polymers, he explains.

The report notes that new polyurethane elastomers, about to be introduced to clinical use, are expected to have a positive impact on cardiovascular devices.

Another promising area, points out Robert S. Langer of Massachusetts

Institute of Technology, is development of polymeric systems for controlled release of conventional and macromolecular drugs. Developing the use of bioerodible polymers for long-term delivery of macromolecular drugs is of particular interest, he adds, because the implants eventually would be absorbed and would not need to be removed. On the horizon is a whole new arsenal of potent macromolecular drugs with short half lives that would need such delivery systems—for example, growth hormones, endorphins, enkephalins, interferon, and luteinizing hormone-releasing hormone.

Another area of high potential is composites, for instance, polymeric composites for blood-contacting devices, and polymer-carbon structural composites for musculoskeletal augmentation. Composites in which one or more phases are absorbable offer promise for applications where healing processes gradually can replace the implant with natural tissue.

As for metal biomaterials, the report suggests exploring new processing techniques that maximize mechanical properties of current alloys, such as hot isostatic pressing and powder metallurgy. Coating processes—for instance, reactive flame spraying, carbon coating, and nitriding—are another possibility for reducing corrosion and thus reducing local and systemic host response. And in another area, according to Klaas de Groot of the Free University of Amsterdam, the Netherlands, bioceramics—based on calcium phosphate salts, mostly calcium apatite and calcium whitlockite—are on the verge of being applied to clinical practice to replace or reconstruct bone.

Areas of greatest clinical need for new biomaterials are listed in the report. Among them are materials that could duplicate the physical and biological properties of various body parts, and hence replace skin, muscles, tendons, and other native tissues; elastomers to replace body components that undergo repeated bending; and materials that can be implanted within the cardiovascular system without risk of blood clot formation.

The report notes in its conclusion that "the biomaterials field is in transition from a cottage industry to an integrated research and product development effort." As several participants observed, biomaterials is having trouble organizing itself as a discipline. There is as yet no uniform set of principles in biomaterials research, with each participating discipline applying its own precepts in an empirical fashion. Thus, an interdisciplinary approach—assembling a critical mass of investigators—is needed. □

New route produces ethylene from synthesis gas

A new entry in direct synthesis of olefins is a process under development at Texaco Chemical Co. for making ethylene from synthesis gas. A two-stage process, it relies on a ruthenium-based catalyst.

Ever since the Fischer-Tropsch synthesis was recognized as primarily an olefin producer, it has been a potential source of ethylene and propylene. But so have methanol homologation and subsequent dehydration, methanol cracking, and the direct synthesis of olefins from synthesis gas.

One or more processes in each of these areas has been suggested, but none has yet reached commercial success.

A number of assessments have leaned toward direct syntheses as being front-runners. One of the arguments in their favor is that the 50% carbon selectivity to olefins that is needed to make the processes competitive with paraffin pyrolysis appears to be achievable by the end of the 1980s.

Texaco research chemist John F. Knifton describes the company's approach: a two-stage process for making ethylene-rich olefins, ethanol, and ethyl esters of aliphatic carboxylic acids. The first stage involves hydrogenation of carbon monoxide to an ethyl ester in the presence of an aliphatic carboxylic acid. The catalyst is a soluble ruthenium species modified with quaternary, group 5A salts. A typical example would be $RuO_2 \cdot H_2O\text{-}[(C_6H_5)_4PBr]$. In the second stage the intermediate ethyl ester may be either pyrolyzed to yield ethylene or hydrolyzed to ethanol.

Knifton believes that the selective synthesis of ethyl esters from synthesis gas and the corresponding aliphatic carboxylic acid is novel. The thermodynamics, he says, are favorable for ethyl ester production, and the equilibrium constant exhibits high sensitivity to temperature.

At least 14 catalyst combinations have been tried. All are more or less productive over a broad range of process conditions, and the highest conversion to esters has been about 94%. The highest catalyst turnover number has been $5.7 \times 10^{-3}\ sec^{-1}$.

The esters formed and the residual ruthenium catalysts are recycled easily. Knifton says that the process appears to be strictly homogeneous since no hydrocarbons higher than methane are formed. There is no evidence for the plating out of ruthenium, and the catalyst does not deactivate with recycle.

Knifton makes several suggestions for mechanisms. Direct ethanol production is ruled out, as is the route via homologation of methanol. The most likely sequences appear to be

$$CO/H_2 \xrightarrow{RCOOH} RCOOCH_3 \xrightarrow{CO/H_2} RCOOCH_2CH_3$$

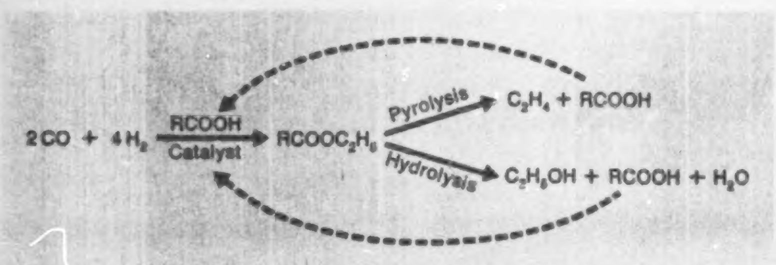
and

$$CO/H_2 \rightarrow CH_3OH \xrightarrow{RCOOH} RCOOCH_3 \xrightarrow{CO/H_2} RCOOCH_2CH_3$$

with the former reaction being the most probable. The second stage also has been demonstrated for ester intermediates.

Most of Texaco's interest seems to be in the pyrolysis of the propionates to ethylene, propylene, and propionic acid in the gas phase. The development work is being continued, Knifton says. □

Ethylene process uses ruthenium catalyst



Basic petrochemicals—1983 will bring late, slow recovery
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Cover: Research associate James W. McNay prepares male-sterile corn seedlings for study at the University of Florida, Gainesville. Photo courtesy of USDA's Agricultural Research Service

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Shakeup ahead for agricultural research

Reorganization of Agricultural Research Service is under way, triggered by charges that research hasn't kept pace with resource depletion and high costs of farming; fight seen over Hatch Act research funds

Wil Lepkowski
C&EN, Washington

A bounty of reports and studies the size of a Thanksgiving feast has streamed from official circles and various think tanks over the past two years. They all say U.S. agriculture is in deep crisis, that it is in need of a revolution in research perhaps as vast as that begun by the epic organic chemist Justus von Liebig, who brought chemical science to farming more than a century ago.

The reports range from a big study of the Department of Agriculture's research bureaucracy by Congress' Office of Technology Assessment to "Empty Breadbasket," a critique by the Cornucopia Project of Rodale Press. That report says each state should be developing a policy of food self-sufficiency in the face of mounting national problems.

One could make after-dinner frolic by assigning to each study the metaphor of mashed potatoes, peas, or pumpkin pie. The turkey, however, would by all odds be "Science for Agriculture," issued by the White House only a few weeks ago. This is more commonly known as the Winrock report after the conference center in Arkansas where it was spawned at a meeting last summer.

Turkey, of course, has opposing connotations—one pejorative, the other gastronomic. And so it is with the Winrock document. The agricultural research establishment in the land grant universities thinks the report is very much a turkey, but the establishment, nonfarm research community is pleased as punch with it. It says among other things that the research at the land grant schools is outmoded and out of phase with today's exciting developments in plant biology. It says that more scientists should have access to that $650 million in agricultural research money that goes directly to universities from states and the federal government. It also says that the Agricultural Research Service (ARS) with its 148 laboratories, 2700 researchers, and $426 million budget does a lot of unnecessary research and needs a wider sense of vision in its perspective on agriculture's problems.

Whether the criticism is really deserved is legitimate grounds for debate. But what everyone appears to agree on is that U.S. agriculture is headed for trouble without a major reform of some kind. Critics say the agricultural system no longer is energy and resource efficient, and thus not geared to relieving the ecological and economic threats endangering the land, the crops, and the farmers that husband them. Bigger and increasingly expensive machinery, rising energy costs, coupled with inflation and high interest rates are sinking farmers deeper and deeper into debt. Meanwhile, the land is eroding when it isn't being contaminated by salt from irrigation runoff. One-species cropping is raising the risk of disease infestation. And the traditional American small farm, the type shown by research to produce most efficiently while retaining soil quality, is fading into history.

At the same time, a revolution in biological research is occurring—one that promises to transform the industries that serve agriculture, and thus, eventually, farming. The innovators are companies like Monsanto, Stauffer Chemical, Dow Chemical, Eli Lilly, Rohm & Haas, Merck, and Du Pont. Each is in the business of selling new products and services to modern farmers and cattlemen. Many of these corporations, through links with top geneticists, biochemists, and molecular biologists in universities in the U.S. and, increasingly, abroad are sowing the seeds for what they hope will be a new industrial revolution in agriculture.

The manipulation of genes has already produced a hoof-and-mouth vaccine to immunize cattle, and a bovine growth hormone to increase milk and meat production. "Genetically engineered soil bacteria to produce fertilizer or to control pests may be possible," says John Marvel, Monsanto's general manager for research. "Within the next 10 to 25 years, we hope to induce plants to be resistant to pesticides, immune to disease, tolerant of hostile environments such as heat, cold, and brackish water, and capable of producing more protein."

But sitting off to the side (some harsher critics would say dozing) are the agricultural experiment stations in the 50 land grant universities. These institutions were established under the Morrill Act of 1860 and

receive federal formula funding under the 1887 Hatch Act. Last year Congress appropriated $221 million in Hatch Act funds while the states chipped in with $500 million more. Most of the new agricultural horizons have brightened, they say, not because of much fundamental research conducted by those institutions but through research supported by nonagricultural agencies such as the National Science Foundation and National Institutes of Health. The critics contend the system needs a shaking up and a revival.

The Cooperative State Research Service (CSRS), USDA's agency that administers these Hatch Act funds, is little more than a faceless, policy-neutral entity to those outside its own 50-state granting system. Yet, these same land grant schools have worked closely with farmers and agribusiness as an effective team.

Moreover, no one wants to wreck something that already is the envy of the world. And no one really wants to end any creative research duplication between USDA's two separate systems of research. But the problems ahead are so vast and expensive that the debate over how to breed a sense of vision into the system could last for years, because not everyone wants to change the same way.

On production data alone, the system—America's largest industry with an asset value of almost $1 trillion—is certainly working. Thanks to the power and creativity of agricultural research and technology—mainly through the fruits of a half century of developments in chemistry and mechanical engineering—this year's harvest of corn, wheat, sorghum, and soybeans is the most abundant on record.

But these crops, plus cattle and hogs, also are selling at record low prices. The economy is so depressed that farmers cannot sell enough of that surplus. When farmers overproduce, prices fall. When prices fall, farmers go more deeply into debt. With deeper debt, more farms fail. USDA predicts that as many as 7% of the country's farmers could go bankrupt this year. And as farmers relay their plight to Washington, the agricultural chemicals industry echoes misery of its own in its 10% drop in sales this year. "There is real concern that next year will be worse than this year," says Jack Early, president of the National Agricultural Chemicals Association.

But there is another form of agricultural economics that the big business of agriculture and the research system that supports it tend to play down. It is this aspect of agriculture—the sustainability, or ecological, factor—that research just recently has gotten around to noticing. It lies in such facts that only 150 separate plant species are involved in food commerce today, versus 5000 at the dawn of agriculture, or that soil is eroding at catastrophic rates in some parts of the country. Is modern agricultural research, built on an industrial production model, therefore destroying the necessary balance between ecology and land husbandry? Or does nature have more resilience than environmentalists and conservationists think? And beyond that, what role does chemical technology and industry have to play in that revival? Will U.S. culture lose that nebulous but nevertheless crucial sense of roots if its agrarian tradition vanishes?

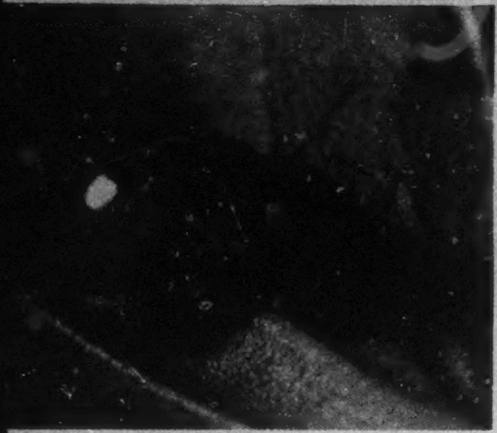
One trouble is that the agricultural research establishment has only half-heartedly probed for answers, built as it is on the large-scale industrial model of mechanical and chemical inputs. A few voices from the environmental, land policy, and organic farming communities were raised during the 1970s, but, except for a period during the Carter Administration, they seldom reached the chambers of official policy either in the states or in Washington, D.C. But they are rising again, and one of the places leading the alternative dialogue is the Rodale Organic Farm Research Center in Emmaus, Pa. This center is funded almost totally by Rodale Publishing Co. and does sophisticated studies of large- and small-scale uses of natural methods of raising yield and controlling crop disease. Another such focus of alternative thought is the Land Institute in Salina, Kan. This privately funded research center, directed by Wes Jackson, studies nonchemical methods of agriculture based on germ plasm derived from disease and stress resistant species of plants native to the Kansas prairie.

"The changes in agriculture over the next 10 years will be greater than those that took place during the past 30 to 40 years," says Richard Harwood, director of the Rodale Center. "We are approaching the end of several frontiers involving cheap water, labor, capital, and energy. And all these are having a powerful impact on farmers. Most farmers with less than a thousand acres will be hurt under these pressures. So we're going to have a dislocation over the next decade or two until we come to a new equilibrium, just as we're reaching a new equilibrium in capital investment."

Harwood believes the rising price of natural gas will transform agriculture irreversibly. "Since 1972," he says, "the price of agricultural nitrogen has gone from 3 cents a lb to 25 cents. The Fertilizer Institute says that by 1986 the price will go up to $1.00. By the 1990s, natural gas no longer will be a source of nitrogen fertilizer."

Harwood says that at 25 cents a lb, it already is cheaper for the farmer to produce his own biological nitrogen by spreading legumi-

Some scientists continue to push their traditional priority for higher crop yields (left), while other scientists try to halt massive erosion problems (above)



Beneficial insects such as ladybugs can replace some chemicals in controlling diseases afflicting crops

nous plants on his fields between seasons. In Delaware, 140,000 acres already are being fertilized with a cover of vetch over the winter. "So we already have passed the threshold there," he says. But Delaware has good soil and rainfall, so it may not be representative of opportunity where the farm belt is concerned. "What the threshold is out there, I don't know," Harwood says, adding that in neighboring Maryland, county agents are opposed to vetch, claiming that it will cause a weed problem.

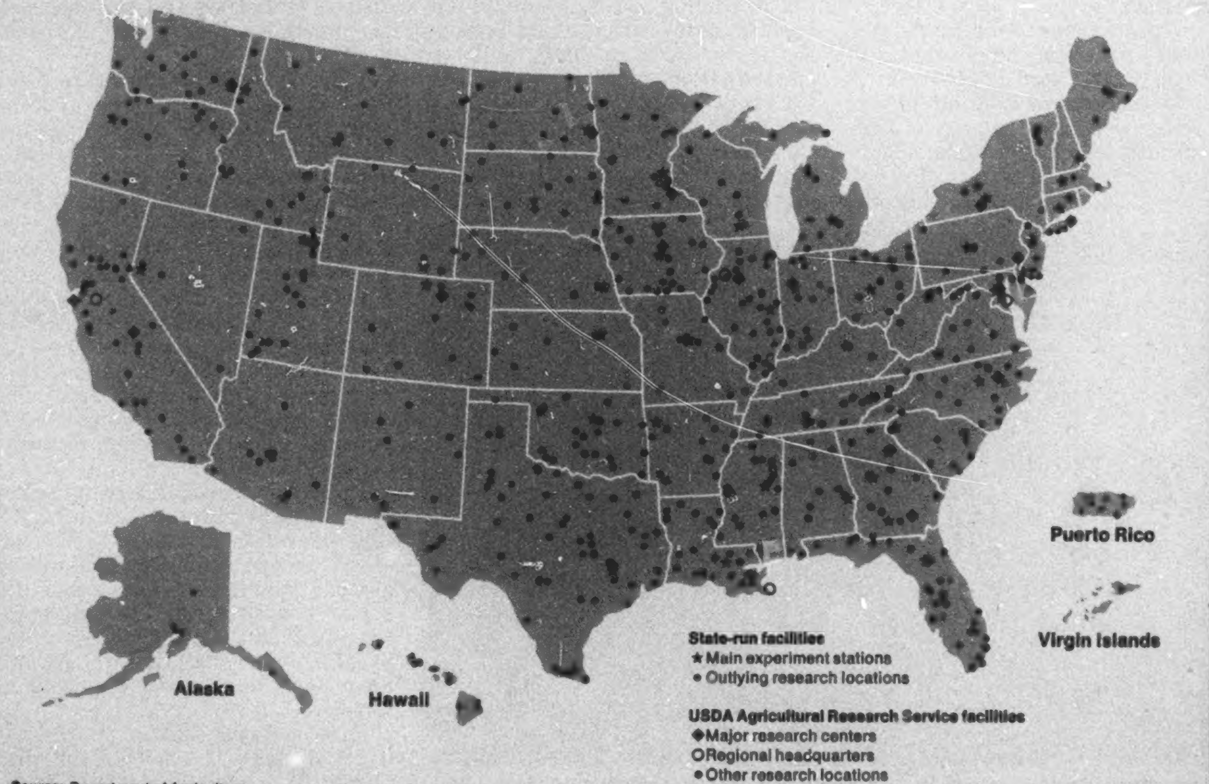
Still, the questions are all part of the transition. What Harwood asks is whether the Agricultural Research Service is aware of the problems coming up and whether it is mounting research on, say, dryland cropping through development of new seed varieties that can tolerate dry conditions. "Moreover," he adds, "are the seed companies foreseeing these problems? Similarly, are the pesticide companies shifting over to biological control research, given the disruptive effects of these agents on the soil?" The answer, of course, is yes, or at least somewhat. Both ARS and the various land grant university agricultural experiment stations have programs in integrated pest management. And, as Monsanto's Marvel points out, seed companies are applying genetic engineering to breed in resistance into chromosomes of important crops.

Edwin M. Wheeler, director of the Fertilizer Institute in Washington, D.C., quite expectedly thinks the natural approach to agriculture is hokum and offers no solution to the farm energy crisis. "This country would starve to death if we went to organic farming," he says. But he does agree with Harwood that natural gas prices will soar once deregulation goes into effect. And to him, the only answer is bigger production for the grain export markets of Japan, U.S.S.R., and China, which are ready with the cash. What Wheeler fears, however, are the developing countries where natural gas is freely flared for lack of ammonia plants to capture it.

"If prices get too high in the U.S.," he says, "these countries would be tempted to produce ammonia." Coal-based sources of methane through big synthetic fuel plants could be an answer, he says, "but you're talking about tons of money to build one of those plants. Still, if you're talking about a U.S. nitrogen industry beyond 1990, it will have to be based on coal." As for the production outlook for U.S. agriculture, Wheeler says the key is exports. "The U.S. fertilizer industry and U.S. farming are absolutely dependent on them. It boggles the mind what this country can produce."

That sounds like a lot of pressure on the system of highly technological,

Government-run agricultural research forms a vast network


Puerto Rico
Virgin Islands
Alaska
Hawaii
State-run facilities
★ Main experiment stations
● Outlying research locations
USDA Agricultural Research Service facilities
◆ Major research centers
○ Regional headquarters
● Other research locations

Source: Department of Agriculture

highly chemical agriculture. But whatever the doubts about the advantages of capital-intensive agriculture, these trends are inevitable, according to Barry Richmond of Dartmouth College's Resource Policy Center. Richmond is conducting a study sponsored by Caterpillar Tractor on the trends in the agricultural system over the next 50 years. Caterpillar's interest, of course, is to forecast some of the farm machinery markets that will develop over that time. The key finding so far, Richmond says, is that soil erosion problems are leading toward the widespread practice of no-till or minimum-till agriculture. Instead of plowing the soil every spring, many farmers now draw narrow trenches up and down their fields and apply seeds, fertilizer, pesticides, and herbicides.

"We believe," he says, "agriculture is being governed by an ethic that is seeking to gain control over the entire system. Today, the family farm doesn't have much control over anything. Not only do farmers have no control over the weather, but they're also at the total whim of the grain merchant. Thus, they can't control the price of their product. And what is going on in the evolution of agriculture is the increasing aggregation in the farm sector. Ownership is getting more and more concentrated. And that kind of evolution is controlling what's getting done to the soil.

"I don't think there's a chance in the world that the system can go back to smaller farms, just as we can't go back to horses and buggies," he says. "The system is going back to no-till agriculture because of two forces: soil erosion and energy prices. Of course, the drawback to no-till farming is the danger of the buildup of pests in the soil. When you don't turn the soil over and leave a crop cover over it, the soil forms an excellent breeding ground for pests. So our guess is that a hybrid form of no-till agriculture will develop, combining till and no-till.

"But what is sure is that no-till will accelerate the trend toward corporate aggregation because no-till requires very sophisticated management. You simply must know a lot about the soil in that kind of agriculture, and that will take sophisticated computer-based management. You have to do a lot of things within a narrow weather window. If you miss that, you're dead because of the very delicate orchestration needed between pest management and fertilizer application. No-till takes a much greater application of pesticides and herbicides.

"What all this means for the ecology is tough to tell. Some chemicals like Paraquat bind to the clay in the soil, which is tantamount to mining the soil. When bound that way, the soil is no longer useful for purposes such as aggregation and pore space. This causes an inherent breakdown in the structure of the soil. Also, these chemicals could leach into the ground water."

But Richmond believes that all these problems are beatable, because "once you get a technological problem defined, you can beat it. We haven't given much thought to a research agenda, but one thing research could do is look more into the benefits of a more decentralized system."

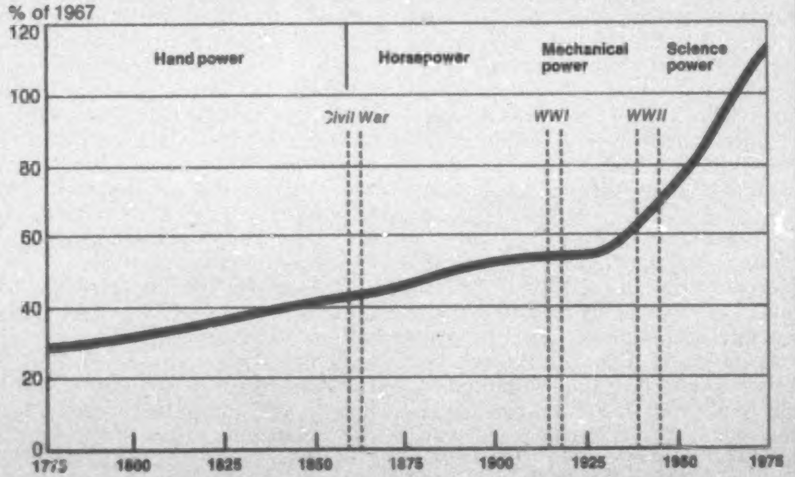
Many changes are happening simultaneously, and it will be the challenge of the experiment stations, agricultural laboratories, and extension services to serve these changes. Like in other segments of society, a historical transition is occurring through the evolution of both technology and a reviving sense of the importance of a land ethic.

Needed first is that bureaucratic fixing, a job that will fall to USDA's new assistant secretary for science and education, Orville Bentley, a biochemical nutritionist and former dean of the University of Illinois agricultural school. Bentley knows he has a big job ahead of him as the official who presides over ARS, CSRS, and the Extension Service. Shifting those elements into a single flowing stream won't be an easy task with a system whose focus is local and ferociously political.

"I wouldn't call what lies ahead a shakeup," he says. "But there is a change taking place that is more rapid than gradual. There will be a swing toward mobilizing our resources toward biotechnology, genetic manipulation. Two other important areas are resource utilization and protection of soil and water. I still think the driving force will be efforts to increase yields, productivity, and production as a way to keep the level of technology high."

Harwood: dislocation over next decade

Farm productivity shot up because of scientific revolution



Source: Office of Technology Assessment

Dennis Prager: rustler at the gates of land grant research

Dennis Prager knew he would be setting off a major political controversy when he and the Rockefeller Institute's John Pino organized the Winrock Conference last summer. To the experiment station directors in most of the land grant universities, Prager is evil incarnate, a no-good varmint, but not by any means to all such figures. The experiment stations at such land grant, research-intensive universities as Cornell, Wisconsin, Illinois, Michigan State, California (Davis), and Purdue have nothing to fear from this latest assault on the system. Their faculties already are competitive with scientists at non-land grant schools and are in fact urging Prager on. Moreover, the American Association of State and Land Grant Universities is giving its support to the Winrock findings.

It is the directors of the stations at the less renowned land grant schools that are after Prager's neck, and a campaign is on through Congress to blunt Prager's zeal if not remove him from his job. But with the protection of the White House, Prager seems safe.

Prager, a physicist, started work as a policy analyst at the Office of Science & Technology Policy during the Carter Administration. During that time he volunteered to take on the issues of agricultural research when a movement that turned out to be unsuccessful was launched in Congress to eliminate USDA's tiny competitive research grants program. "I found the agricultural research community to be complicated, factioned, and not like any other research group," he says. "Even if you knew a lot about NIH and NSF, you still wouldn't know anything about the ways of agricultural research. So I immersed myself in all aspects of agriculture and found myself giving talks all over the country to willing audiences."

C&EN staff photos

But over time, Prager says, he came to be concerned with the quality of research at most of the land grant experiment stations and the degree to which the system was taking advantage of the tremendous amount of research going on outside agriculture. He says he wondered about the isolation of that system and found that a lot of people he respected shared this view. These were the people that were invited to Winrock.

"I began to feel there were problems that needed to be addressed, and then began running into tremendous hostility from the land grant community, especially in the Midwest," he says.

The speechmaking over, Prager and Pino then organized the conference. The report has been sent to Congress, and hearings are expected before the House Science & Technology Committee.

What is certain to happen are efforts to spread Hatch Act funds more widely through the research system. Whether it will succeed, however, is highly doubtful in the face of a land grant community loaded for bear. Prager says he is surprised at the ferocity of the response from the land grant opposition.

"They are well organized, conservative, and paranoid," he says. "Once they understand where the momentum is going, they try to spot the people behind it and rub them out. They are saying I'm trying to destroy the agricultural research system. They feel that the system is over 100 years old, it's productive, and doesn't need change."

Prager says he isn't out to kill the experiment station system. He says he doubts whether much ARS research needs to be done at sites where experiment station research goes on. But he thinks, as the Winrock report says, that ARS should be taking the longer-term, national view of agricultural problems. Much of the experiment station agenda is wholly legitimate, he says, and only a fool would want to scrap it.

"What I do know is that we have the most productive farmers in the world," he says, "and they are going to bust hand over fist. The bottom line is that if you draw a fence around ARS and the experiment stations, they are not producing enough basic knowledge to sustain productivity of American agriculture."

But the U.S. must address these harder issues, he says, "like the condition of the soil, the problem of rural America, the importance of agriculture for [the U.S.] balance of payments. [The U.S.] built an agriculture based on abundant natural resources. Now [it has] to find solutions for the benefit of society as a whole.

"I remember as a boy on the family's North Dakota farm the dust storms of the 1930s. Mile after mile of the soil was being plowed up, and we saw the consequences. Once you've been in a dust storm you never forget it. There should be a national goal to return fertility to the soil. And [U.S. farmers are] going to have to use organic fertilizers because the volume of chemicals needed is too great."

What Bentley sees is more federal involvement in changing the course of agriculture toward more conservation again. That will mean diversion of funds at a time when the Reagan Administration could be facing a budget deficit as high as $200 million for fiscal 1983. Otherwise, he says, he sees farms becoming larger and larger as farmers can no longer keep up their production to make enough of a profit.

Refocusing his agencies will be quite a job, he admits. And it will take a while. A year from now, his outside advisory group, the Council for Agricultural Science & Technology, will submit its report on what the Science & Education Administration should be doing to meet the challenges ahead. The chairman of the Council currently is Emery N. Castle, director of Resources for the Future, a Washington, D.C.-based research group. Castle himself made one of those assessments of agricultural research that appeared over the past two years. But Bentley already knows what the problems are, and there may be no time to wait for yet another report on U.S. agricultural research needs. ARS is already reorganizing for a longer range assessment and national policy role.

"It is going to be difficult to set goals with regard to specific scientific development, because so many different things are going on in agriculture all over the country," says Bentley. What he means is that agriculture is fundamentally local, and so any attempt to turn the experiment stations around toward a better blending with national goals

John Dunbar: a Kansas State hoosier takes on elite science

Anyone talking about amber waves of grain has to have the state of Kansas in mind. As much as any state and certainly more than most, the story of Kansas agriculture is one of an increase-and-multiply fusion of farmers, land, and technology. In these late autumn days, Kansas is green, laid over with a lush carpet of winter wheat, which will be harvested next summer. Once prairie, Kansas is now prime agricultural land, blessedly fertile and well watered in the eastern part, dry and once-sparing in the west. But western Kansas wasn't long left to its natural ecology. For under it lay the Ogallala aquifer, an enormous underground sea of ancient water that for the past 30 years has been pumped for the irrigation of a most unlikely crop: water-guzzling corn, grown to feed cattle all over the world.

There's a fierce pride that shows through John Dunbar when he talks about the Kansas State University Experiment Station. Dunbar is its acting head and is dean of agriculture at the land grant university. Currently he's not reacting any too happily to the Winrock Report's attack on experiment station research. He thinks it is born of snootiness, ignorance, and avarice.

On top of all that, Dunbar loves farming. On his farm in his native state of Indiana, Dunbar raises soybeans, corn, and popcorn. He believes any large-scale use of organic farming is romantic idealism, and he freely acknowledges that his experiment station exists for the industrial model of agriculture. Indeed, agribusiness is far from a dirty word in Kansas. Without agribusiness—the complex system that supplies seed varieties, fertilizer, machinery, irrigation systems, and agricultural chemicals to farmers—Kansas agriculture would have gone bust a long time ago.

But in this age of agricultural exports and balance of payments problems, he thinks that agriculture on an enormous scale and intensity is the path to the future. It's expensive agriculture with no room for the little man. Say what you will about intensive agriculture depleting the soil, ruining and wasting water supplies, and raising tolerance to pests, Dunbar believes that research will solve any problems that come along. Farmers, in fact, do use organic forage techniques to supplement their chemical fertilizer input, he says. Even when energy costs get too high to pump water in western Kansas, research will help the farmer return to dry-land farming. Only this time such agriculture will not succumb to the climate's vicissitudes, which the sod-house homesteaders had to endure during the late 19th century. This time, fancy and fanciful seed varieties, conservation practices, fertilizers, and farm chemicals will ensure a productive new era. Water-intensive farming is fading from western Kansas and Dunbar knows it. But it's no reason for panic, he believes.

So in Kansas, confidence in agricultural research looms eternal, if only the elitist research reformers would keep off the backs of the states. In the past, cattle rustlers used to invade ranches and make off with prime livestock. This time the rustlers are making a raid on experiment station research funding and Dunbar is fixing to put up a strong fight.

"No one knows what they're talking about when they say we don't do basic research here," Dunbar says. "Nor do the same people know anything when they say we don't do peer review at places like this." Dunbar's "places like this" hardly fits the experiment station stereotype: a Victorian structure staffed by aging researchers at the fringe of the campus. At KSU, the station is in reality a system of funding research and setting its priorities among 32 departments competing for those Hatch formula funds. There are, however, five branch stations around the state, each dealing with the farm problems in its particular area.

Nor is the picture of a single titular head dispensing Hatch Act funds on eccentric whim anywhere near the truth. Hatch funds are distributed by in-house review committees. Those who are producing good research get funded. Those who aren't competing in their fields get left out. Many of the younger faculty members are earning more money than some of the older staff.

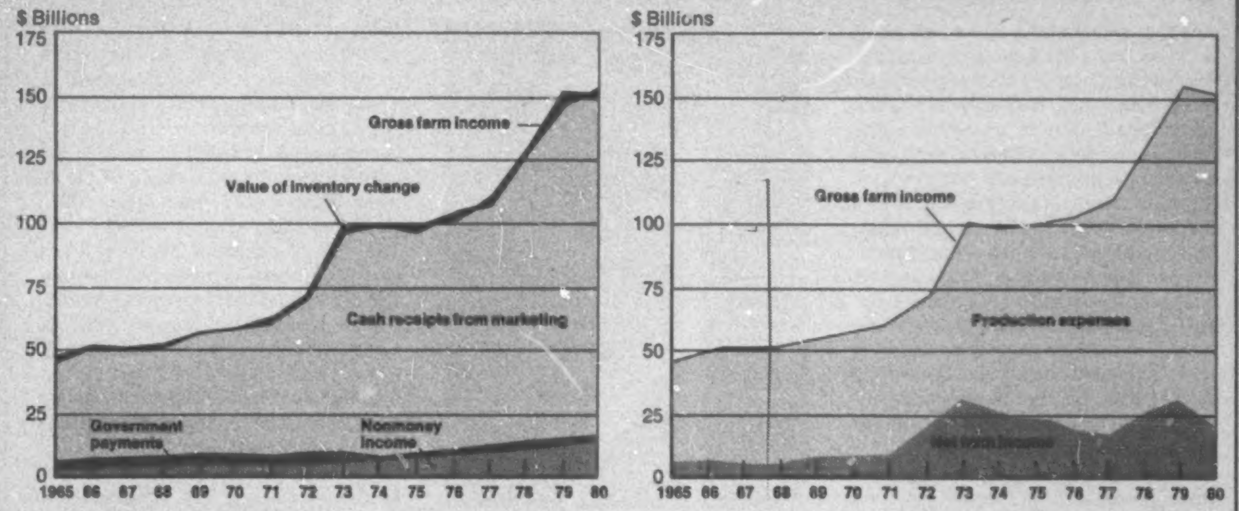
Kansas soil, especially in the more rainy eastern section, is eroding much faster than it is being formed. In the western part, the Ogallala aquifer is indeed being mined much faster than Rocky Mountain runoff is replenishing it. The energy costs for pumping it are straining farmers' budgets, and many are leaving agriculture. Mostly the already rich are surviving and growing. Although Kansas law prevents the purchase of farms by big corporations, nothing forbids families like the Gigots of western Kansas from becoming conglomerates in their own right. The Gigot success story—they started with only a few acres and little money—is in fact the farmer's epic dream.

A gap stretches between Dunbar's industrial paradigm and that of places like the Land Institute in Salina or the Kansas Rural Center in Whiting. At the Land Institute, a few well-educated mavericks led by Wes Jackson are teaching and practicing an agriculture aimed at restoring diversity to Kansas agriculture. Research is being done, for example, on perennial grains that are more native to Kansas soil. At the same time, they are trying to preserve a romantic sense of farmers and land that they believe is being lost under the industrial model.

Jackson thinks that big companies, like the combination of Pepsico and Prudential, that have operations in Kansas are showing scant concern for soil conservation. And he is especially critical of Ogallala irrigation practices in western Kansas. "What [these big companies] are doing," he says, "is using that water to create a desert. I really blame the land grant institutions for what's happening. They exercise very little leadership. They discovered the parade and they got ahead of it. Dunbar is transient. But the forces that put him there aren't. I'm happy to do battle with them. I look at the farm as a hearth; they look at it as a factory."

But Dunbar says farmers have no time or inclination to go back to a style of agriculture that will lower yields or reduce income for a year or two. They already owe too much to the banks from loans on expensive farm equipment and land purchases. Whether there will be a showdown of values in Kansas, however, is doubtful. The existing system will go its way; the Land Institute believes its values eventually will work their way to the top.

Farm income comes mostly from marketing and goes mostly to pay production expenses



Source: Department of Agriculture

could be wishful thinking. The experiment stations already are proud enough of what they do. In fact, the stations say that what they do is often better and more relevant than what ARS does. Also, they will fight any attempt by the non-land grant institutions to make off with Hatch Act money. Kansas State University dean of agriculture John Dunbar says his budget is already worse than tight. He says his science departments have 32 research and teaching vacancies to fill as it is.

But what Bentley says will be done are investigations into diverting some of the farm subsidy money, $7 billion or so, toward research and conservation. That will involve a fight. Also, there's considerable sentiment toward siphoning off to the reconstituted, refurbished ARS and the USDA's competitive grants program some of the agricultural research funding NIH and NSF distributes to scientists at non-land grant schools. What Bentley will get is plenty of outside advice. His units already are the target of plenty of criticism.

"There is no question," says one plant researcher outside the land grant system, "that USDA is a fat bureaucracy. The regional laboratories represent a lot of the worst research, but although good science is still going on there, there's not a lot of it. We have to encourage the good ones to keep doing good research and weed out through retirement the others.

"People like Prager would like to scrap the whole system and build a new one; it's cleaner doing it that way," he continues. "But we don't know enough about what makes bureaucracies encourage mediocrity. So there's no assurance that putting a lot of young people in the system wouldn't create in 10 or 15 years the very same problems we're complaining about today."

William E. Marshall, a biochemist who is technical director in the development sector for General Foods Corp., has been studying federally funded agricultural research in his assignment as a member of President Reagan's Task Force on Cost Control. As he sees it, USDA as yet has no long-term goals that it is moving toward.

"What is clear from my studies," he says, "is that the state agricultural experiment stations are in danger of losing their pre-eminent role in agricultural research. There are two reasons for this. As agribusiness grew, the research system became mature and as a result needed a lot of maintenance work. That was time and money taken away from research. [The stations] had to keep track of new pests, evaluate new fertilizers, and the like. That prevented growth of real research. Second, it was becoming evident that the future of agricultural advances lay in developments in plant biology, and the best work was being done outside the system. Animal science is the same story. My feeling is that we don't have yields up as high as we could in livestock. We're now importing some strains of pigs from China, for example, because their litters are greater."

Marshall is unsure whether USDA will be able to adapt to gain preeminence in research. "I don't feel that it has the level of fundamental science under its control or within its sphere," he says. "What's needed is to bridge the gap between molecular biology and the future of agriculture. The system isn't really running at top capacity. There's a lot more it can produce."

Hugh Murphy, professor of agronomy at the University of Maine, speaks with Yankee practicality in his comments on the Winrock spate. "I saw some of that report," he says, "and it looks fine but it didn't get down to the nitty-gritty of things. The farmer wasn't really spoken for in the report, and although I can agree with the fascination of molecular genetics and biotechnology, most of the research there won't find practicality for 10 or 15 years. Even developing new breeds and strains takes 15 years by the regular plant breeding way before they're ready for the field. Besides, you're talking about new farming practices when you develop a new strain." And speaking for potato research, his specialty, Murphy believes that much more knowledge already lies on the shelf than can be used.

But where Murphy turns away from his conservatism is in his criticism of ARS research. "ARS got started for the purpose of doing research of the basic type that experiment stations were not able to do. The trouble is that when Congress came to appropriate money, it would ask what ARS had accomplished and so it got into more applied areas. So now ARS is doing a lot of the same research the experiment stations are doing. I contend that when you have two units doing the same research, one of them is wasting money. Then, when I ask who should be doing that research, I also ask who is closer to the grass roots."

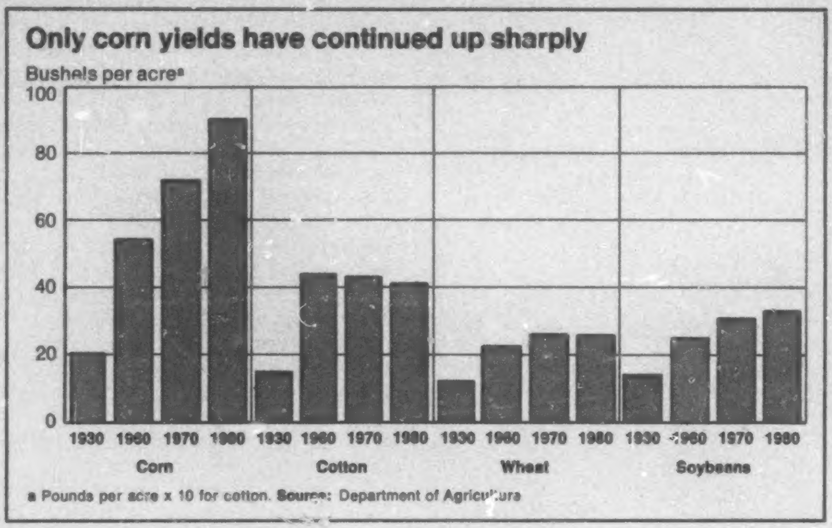
ARS director Terry B. Kinney is aware of all the criticisms and says that in the big review of his agency now taking place, 5 to 10% of ARS's 148 laboratories will be closed or sold off. "There are powerful changes ahead," he says, "and as we look at our strategic plan and the redirection of our programs we'll have to carry out our redirection rapidly. We will have to tell scientists that they will have to move and start new careers in new fields of research. At the same time, we're taking a hard look at administrative costs. Currently 14% of our budget goes into those costs. We want to cut that figure to 12%. That may not sound like much, but it means releasing several million dollars more for research."

Kinney believes ARS research is much better than the public's image of it, pointing out, for example, that the new bovine vaccine for hoof-and-mouth disease developed through genetic engineering was a product of ARS's Plum Island, N.Y., facility. He says many ARS laboratories have top research groups, and he plans to underscore the work of these centers of excellence. The best places will get increased funding and researchers.

He also thinks USDA's competitive grants program, now funded at only $16 million, should rise to "at least $100 million." He says he isn't interested in having management of that program transferred to ARS, a move that would make ARS parallel in function with NIH. But he does think there could be better coordination of the external funding of agricultural research with the large overview ARS has of research priorities. He is piqued, however, at the new attention agricultural research is getting from the general research community.

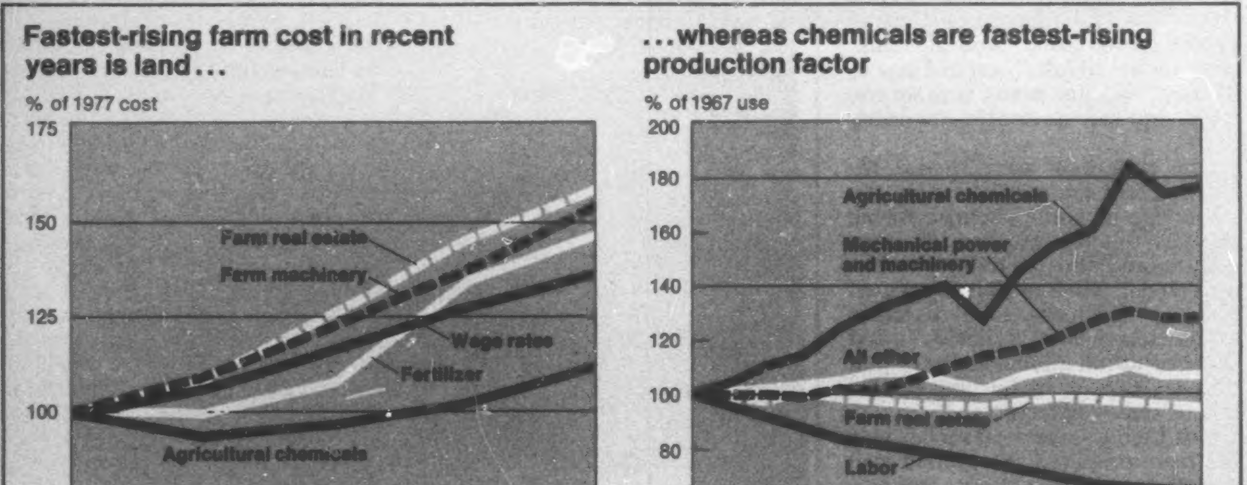
What is certain about the agricultural research system is that it isn't very tolerant of glib solutions. It's complex and as such doesn't really exist as one system. There is the system of individual pest control for individual crops. There is a system for producing new seed strains to enable, say, the growing of soybeans in the northern plains states. There is a system for the purchase of instrumentation for agricultural field-station laboratories, and obviously each crop is a system in it own right. In short, each agricultural specialty has its system, or information network.

Where this system is being systematized, as it were, is in the agricultural extension services at the county agent level where relevant information from the laboratories must be brought to the needs of the farmers. Here, computerization is coming on fast and this development alone is what could change the shape of U.S. agriculture in the needed biological and land policy directions. That is, it may force the formation of a "metasystem," some combination of conservation values, even in their more romantic aspects,



Only corn yields have continued up sharply

a Pounds per acre x 10 for cotton. Source: Department of Agriculture



Fastest-rising farm cost in recent years is land...

...whereas chemicals are fastest-rising production factor

a Preliminary. b Estimated. Source: Department of Agriculture

Terry Kinney: aware of criticisms

C&EN staff photo

Bentley: create one national system

which will preserve the kinds of values the Richard Harwoods and Wes Jacksons want to see protected.

One problem seems to be that of accountability for decisions. The administration of research appears to be scattered throughout the USDA bureaucracy. "No one knows who is accountable for developing research priorities around various crop and animal research," declares Joseph Kinney, staff director of the committee on agriculture of the National Governors' Conference.

Kinney says the governors will be paying a lot more attention to agricultural research problems over coming months in efforts to improve state-sponsored agricultural research. If the federal government fails to cut back military research, and if agricultural research needs are so great, then states are going to have to pick up the slack. "And the situation looks bleak," according to Kinney. "We just aren't sure we can make up the domestic spending cuts."

One aspect of agricultural research's problem may be a scientific self-image. Organic chemist Liebig was the founder of chemical agriculture, and thus of today's industrial model, when in 1840 his paper, "Organic Chemistry in Its Relation to Agriculture and Physiology" stood the agricultural establishment of that time on its head by burying the old humus theory of fertility.

But Liebig's chemical model may not have prepared the system well enough for the era of limits and also may have narrowed the perspective of science in its service to human and agrarian values.

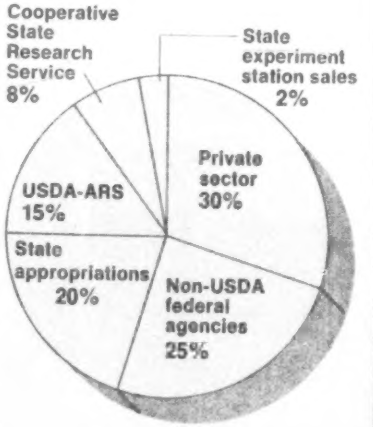
Stan J. Dundon of the University of Delaware's Center for the Study of Values, thinks so. To gain acceptance among peers, scientists must pursue research, and publish on highly specialized topics. Agricultural scientists, many isolated in laboratories and divorced from the farm, are under the same influence. They seek reputations among their fellow disciplinarians, not necessarily among farmers, and certainly not the "muck and mystery" pursuits organic agriculture represents to them, even if it might represent a cheap cure to some big problems. Liebig's descendants likewise can't be expected to leave their molecular pursuits to measure the impact of native species of legumes on soil fertility.

And, says Dundon, even if today's scientists recognize the benefit of developing nitrogen-fixing qualities to nonleguminous plants, the brightest and most ambitious among them will choose recombinant DNA research as the approach. They are unwilling to squander their careers by drably searching out nonconventional native species of plants that might be bred as natural sources of nitrogen. This is what the Land Institute is doing.

"This DNA research," Dundon points out, "is typical U.S.-based laboratory, home campus research. Highly specialized articles are published in disciplinary journals, leading to promotion in publish-or-perish disciplinary departments, and remunerative relationships are established with appreciative clientele."

A composite picture of the germ plasm collector, on the other hand, he says, "is that he or she is funded by the Mennonites, out slogging in the jungle or on mountainsides, finding promising new species or adapting them from native farmers and running tests on them, studying the social and economic factors needed to integrate the innovations into village farming systems, writing in interdisciplinary journals, and ending up as curators of botanical museums."

Government big supporter of agricultural research



Total funding = $2.5 billion, fiscal 1981

Source: White House task force

But it isn't only establishment research in agriculture that may have the problem. Its critics from basic science may themselves need another form of agrarian sense. Vernon J. Ruttan, University of Minnesota agricultural economist and author of the just-published book "Agricultural Research Policy," thinks so. "It is time," he says, " for the general science community to begin to follow the lead of the agricultural science community in embracing the fusion of science and technology rather than continuing to hide behind the indefensible intellectual and class barriers that have been retained to protect its privilege and its ego from contamination by engineering, agronomy, medicine, and the social sciences.

"This change will become increasingly important in the future as the close of the fossil fuel frontier joins with the close of the land frontier to drive technical change along a path that entails the emergence of a much larger role for biological and information technology."

On that thought, the Wes Jacksons and the John Dunbars can grip the same till, or carve at the same turkey. □

Petrochemicals inch toward recovery

Following a low in output this summer, basic olefins and aromatics are starting the long road back to financial health

Bruce F. Greek
C&EN, Houston

U.S. petrochemicals have been knocked flat financially and generally are operating in the red. It is long past time for the recovery once hoped for in the second half of 1982. Some industry people are now pinning their hopes on the second half of 1983, but others aren't looking for full recovery until 1984 or respectable profitability until 1985.

Currently, production rates of the five major petrochemicals treated in the following pages—ethylene, propylene, butadiene, benzene, and *p*-xylene—have inched up from the summer trough. But output at a combined 51.8 billion lb for 1982 remains fully 20% below 1979 peak levels and in some cases is still below levels of a year ago, when the production slump was in full swing.

A production upturn in 1983 might not exceed 10% and could be as low as 5%. That would leave combined volume of the five well below 1981's 60.0 billion lb, to say nothing of 1979. In fact, it would take a further 10% pickup in 1984 for output to exceed 1979 levels. Even then butadiene and benzene might not make it back, given their sluggish growth forecasts.

If petrochemicals' volume picture is bad enough, the value side is even worse. Severe pressure on prices has hammered down combined production value of these five petrochemicals by an estimated $3.5 billion, or nearly 25%, in 1982 from about $14.5 billion in 1981. A 10% volume rebound in 1983 might add only $1 billion to sales. Another 10% volume gain in 1984 with stronger prices might bring dollar sales back to the 1981 level.

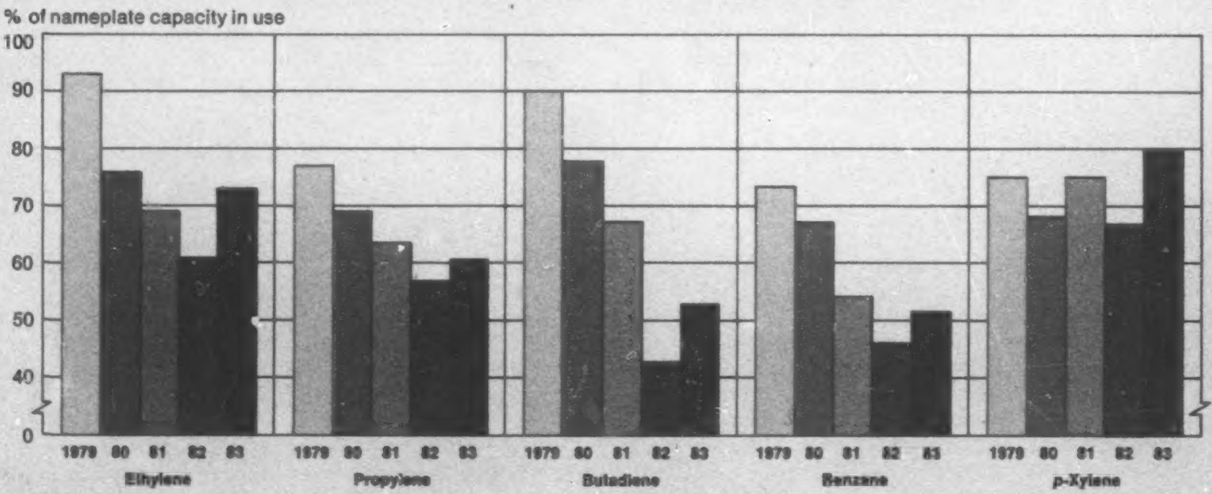
But even this slow improvement is considered optimistic by many analysts in the industry. Top managements have become similarly cool, overriding proposals for any kind of plant expansion except for certain specialty grades. New investment is being pruned continuously, and current plant spending is going largely to complete projects begun one to three years ago.

Operating costs also are being pared where possible, although the big savings here, from feedstock switching, already have been made. Since little new-plant investment is due until late in the 1980s, this feedstock cost factor will be the big one facing producers. This year, as in the past several, a shift has continued toward the lightest possible feedstocks for steam crackers even at the loss of coproducts. These light hydrocarbon raw materials—ethane, propane, and to a lesser extent butane—are still cheaper than heavier gas oils or naphtha despite a large price increase this year.

Later in the decade, the light hydrocarbons' cost advantage could fade, according to some industry analysts. By this view, lower demand for natural gas will reduce new gas discoveries and, with them, the availability of new ethane and propane. In addition, natural gas will continue to be drier (contain less separable ethane and propane liquids). Gas prices would increase, pulling light hydrocarbon prices along with them.

The current consensus is that from now until 1985, ethane, propane, and butane will be used as much as possible even with rising gas prices. As a result, more propylene, benzene, and *p*-xylene than usual will come from refinery streams, and butadiene imports from Western Europe could continue to rise. □

Plant-use rates finally may turn up if gradual recovery starts in 1983



Sources: Industry, C&EN estimates, International Trade Commission

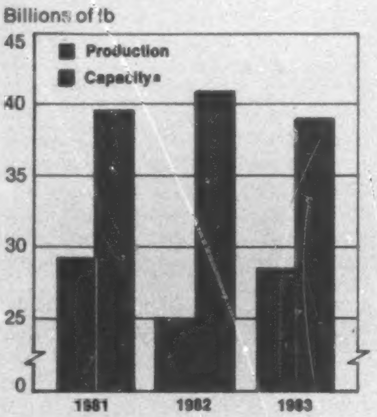
Key Chemicals

$CH_2{=}CH_2$

Ethylene

- ***Demand in trough***
- ***Capacity chopped***
- ***Prices reviving***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from natural-gas-derived ethane to oil-derived gas oil (fuel oil)

MAJOR DERIVATIVES (U.S.)

Polyethylene 45%, ethylene oxide 15%, vinyl chloride 15%, styrene 10%

MAJOR END USES (U.S.)

Fabricated plastics 65%, antifreeze 10%, fibers 5%, solvents 5%

FOREIGN TRADE

Negligible

PRICES

List prices mainly 21.5 cents per lb

COMMERCIAL VALUE

$5.0 billion for production, 1982

With U.S. production far exceeding output of other major olefins combined, ethylene is a good proxy for the whole sick petrochemical industry. Petrochemicals have been sandbagged financially, and ethylene, sure enough, is one of the more exaggerated cases.

Currently, ethylene seems to be at the end of a year-long shakeout. Sagging demand has led to production and capacity cutbacks. After all this, 1982 output probably will total only 25 billion lb, possibly a bit less—down 15% from 1981. Since actual demand this year for ethylene could reach 27 billion lb or so, inventories have been slashed nearly 2 billion lb.

Whether the inventory reduction is over will be important to ethylene's prospects in any economic pickup in 1983. Industry analysts present several cases. At worst, ethylene demand would be almost stagnant in 1983 with continued downward pressure on prices and output. This would call for a further tug on inventories. More optimistically, demand would pick up, especially in the second half of 1983. That would induce inventory building and raise production over demand for the year. Presumably, the second case would mean stronger prices, making a larger inventory more affordable.

Prices can have such levered effects in a year like this one, when they have changed almost unimaginably fast. Prices plummeted last winter, from a real market level of 25 cents a lb to below 17 cents by spring. Then in the summer as feedstock prices rose, especially spot prices of ethane and propane, ethylene list prices went back up to the low 20s per lb. Discounting now holds real prices close to 20 cents.

That means ethylene prices have not risen as fast as have skyrocketing prices for the dominant light hydrocarbon feedstocks. Ethane has about doubled to 28 cents a gal and propane is up nearly as much proportionately to 50 to 55 cents a gal. About the only feedstocks down in value are the less desirable refinery raffinates left after aromatics are removed from the product streams of catalytic reformers. These raffinates may continue to be low valued, seeking an alternative market to slumping use in gasoline.

Relatively low ethylene prices hurt overall company profitability in two ways. Little net income comes from ethylene itself. In addition, low prices for ethylene cause buyers of the same companies' ethylene derivatives to expect low prices for them as well, severely limiting returns in downstream processing.

With low profitability come low plant operating rates, plant shutdowns, and scrappage of some capacity. At this time, at least 5 billion lb per year of annual nameplate capacity is still shut down "temporarily."

But some capacity is gone forever. During the past year, about 2 billion lb per year of ethylene capacity has been closed permanently. These include small units that processed refineries' off-gas streams as well as older steam crackers.

Since most of the ethylene units taken down in 1982 hadn't run for some time, average nameplate capacity for the year was unaffected. At 39.5 billion lb, this capacity had an average operating rate of 63%, a bit higher than the average estimated for mid-year (C&EN, Oct. 11, page 12).

In 1983, the operating rate for ethylene plants likely will rise substantially. Production could be up nearly 15% to 28.5 billion lb, the midpoint of an opinion range from industry sources—even with some inventory cutting to meet demand. Therefore, the 1983 operating rate might easily be 10 percentage points higher. If more scrappage occurs, the use rate could easily reach 75% of nameplate capacity.

Such production depends on a substantial upturn in demand for currently weak derivatives such as vinyl chloride and a lesser, but still strong, upturn for less depressed derivatives such as polyethylene. Most ethylene derivatives will not make it back to 1981 levels in their 1983 use of ethylene, but they should be getting close.

Such a recovery will return the use pattern of ethylene to normal after small changes in 1982 as polyethylene gained at the expense of vinyl chloride. What will not return to past patterns will be ethylene's production growth rate, now permanently lower. After pushing up an average of 6% per year from 1969 through 1979, ethylene now will be lucky to go at half that pace in the 1980s.

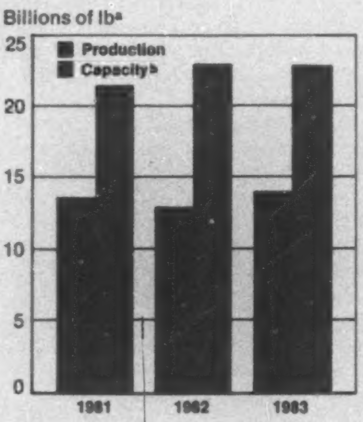
Key Chemicals

$CH_2{=}CH{-}CH_3$

Propylene

- ***Production off a bit***
- ***Capacity flat***
- ***Prices down***

PRODUCTION/CAPACITY



[a] Chemical and polymer grades. [b] First quarter.

HOW MADE

Recovered from cracked gas streams made in olefins plants and oil refineries

MAJOR DERIVATIVES (U.S.)

Polypropylene 25%, acrylonitrile 20%, cumene 10%, 2-propanol 10%, propylene oxide 10%

MAJOR END USES (U.S.)

Fabricated plastics 50%, fibers 15%

FOREIGN TRADE

Exports—negligible, imports—holding at about 500 million lb in 1982

PRICES

Chemical grade 19.5 cents a lb, polymer grade 21 cents a lb

COMMERCIAL VALUE

$2.75 billion for production, 1982

Propylene has an image problem. It has to exist in the shadow of ethylene and gasoline in spite of a large increase in both its use and relative value over the past decade. It is still classified as a coproduct—ethylene's in the case of olefins plants' steam cracking or gasoline's in the case of refineries' catalytic cracking. Seldom is it made on its own.

As a coproduct, propylene plays an economic support role. It can help steam cracking, for instance, by contributing scarcity value when ethylene demand and prices are low. But it hinders refining economics through the additional processing costs needed to make it into a useful component of gasoline.

In all sources, to get something from propylene, purification is needed. So both kinds of producers have to add propylene splitters. For this equipment, economics work best if capacity is large enough to handle all available propylene for some time to come.

Such economic considerations help explain the large excess plant capacity and low use rates in U.S. propylene. If 1982 propylene production falls only 4% from 1981 to about 13 billion lb, available capacity will run at a lowly 55% of nameplate capacity of 23 billion lb per year. Next year, capacity utilization probably will be up a bit, to perhaps 61%, if production goes over 14 billion lb and capacity holds.

Capacity for propylene is hard to pin down. Designers can always push up capacity of the distillation towers for purifying propylene simply by adding to diameter. Such excess capacity can be useful when a producer with a ready market finds a chance to purchase a cheap hydrocarbon stream containing propylene. The tricky part is that the tower's capacity for propylene depends on factors such as concentration of propylene in the feed and purity of product needed—chemical or (higher) polymer grade. Depending on these factors, capacity is either over- or understated. Industry sources estimate that the actual total capacity range could be from 20 billion lb to 26 billion lb per year.

Because propylene units are relatively easy and inexpensive to shut down and restart, they have to be counted as operable even though long out of action. Currently, there is a lot of such capacity in refineries that likely will never run again.

If at some point ethylene demand picks up at the other propylene source—olefins plants—and feedstock needs exceed supply of light hydrocarbons, more gas oil (now shunned because of high cost) will be used to make ethylene. Coproduct propylene of necessity will be larger. Since steam-cracker propylene must be either sold or burned as fuel, it will not only tend to force a market but also control the propylene price at all sources, including refineries. With such a potential competing supply bulge over their heads, refiners may not restart their propylene towers even if both gasoline and ethylene demand surge when the economy recovers.

For the near term, however, more propylene than usual will come from refineries. One reason is the low propylene yield from steam crackers, which still favor ethane and propane feedstocks. The second reason is the current high cost of isobutane, which refiners react with propylene to produce an alkylate to blend in leaded gasoline. Given the high price of isobutane, refiners' interest in alkylation has sagged, and they are pushing surplus propylene into chemicals.

This movement of refinery propylene into chemical and polymer uses pushed propylene prices down during the third quarter. The propylene price is now about equal to ethylene's after sporting an unprecedented premium earlier this year. Analysts feel, however, that the propylene price is unlikely to resume its old level of 70 to 80% of the ethylene price.

The largest use of propylene, polypropylene, has been hit hard by declines in two of its major end-use markets, housing and automobiles. Polypropylene production through August fell 17% from 1981. Sales declined less, indicating a slash in inventories, according to the Society of the Plastics Industry's Committee on Resin Statistics.

Because of low overall expectations for early 1983, prospects for full-year propylene production are for a modest increase of 7 to 8%, with most of that coming in the second half.

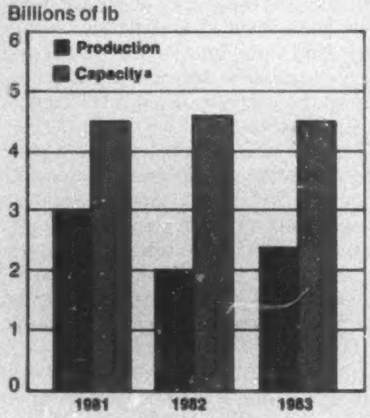
Key Chemicals

$CH_2{=}CH{-}CH{=}CH_2$

Butadiene

- ***Production way down***
- ***Capacity declining***
- ***Prices torpedoed***

PRODUCTION/CAPACITY



a First quarter; includes all extraction capacity.

HOW MADE

Recovered from steam-cracker product streams; dehydrogenation of butylenes from oil refineries

MAJOR DERIVATIVES (U.S.)

Styrene-butadiene rubber 40%, polybutadiene rubber 20%, hexamethylenediamene 10%

MAJOR END USES (U.S.)

Rubber products 70%, fibers 10%

FOREIGN TRADE

Exports—holding at about 70 million lb in 1982, imports—rising to more than 700 million lb

PRICES

List price 31 cents a lb

COMMERCIAL VALUE

$600 million for production, 1982

In the odd world of butadiene, at least one thing is pretty clear. Its market essentially means rubber, and rubber, in turn, means transportation as the main end use. In this recession year, transportation—in terms of auto manufacture and tire use—has slowed to a crawl. Although demand for butadiene held up remarkably well through 1981, it fell hard this year, and recovery will be painfully slow.

The transportation setbacks in 1982, including an auto production rate barely half that of peak years, have crippled butadiene. It has suffered more than most other big-volume petrochemicals. Production in 1982 will do well to exceed 2 billion lb, off by one third from 1981 production. Many plants, including all independent dehydrogenation units, currently are shut down. They will not be restarted before late next year, if at all.

Some of the dehydro capacity is down for keeps. For example, Copolymer Rubber & Chemical's Baton Rouge, La., plant is closed permanently and will be removed. Some by-product butadiene capacity also is largely out of the picture, the result of 2 billion lb per year of ethylene capacity being permanently closed in 1982. In the case of steam crackers in these shutdowns, the extraction capacity for removing and purifying butadiene has not generally been scrapped and is kept available for intermittent use.

Because so much extraction capacity for butadiene waits in the wings, still counted as operational, the overall plant use rate for butadiene has fallen to an unusually low level, 43% for 1982. A slight recovery may occur by the end of the year as ethylene operations improve and inventories of butadiene approach record low levels.

Despite the low official operating rate, steam-cracker operators are still processing all the butadiene the crackers can turn out. The trouble is, basic butadiene output from steam crackers is down because of the shift to ethane and propane feedstocks. Such feedstocks produce very little coproduct butadiene compared to heavy-liquids feedstocks such as naphtha and gas oil. Barring another price explosion in ethane and propane, the lightest feedstocks will continue to give the lowest-cost ethylene. A slight shift away from ethane and propane may be in the cards for part of 1983, but the change probably will not be large enough to add very much butadiene output.

Possible reopening of the independent butadiene plants in 1983 will depend on several economic influences. Fuel cost, mainly for natural gas, is important as is cost of raw-material butylenes. As with so many other petrochemicals, butylene costs are influenced strongly by their alternative value as a material for gasoline. Behind the scenes, then, gasoline vagaries, such as the ratio of leaded to unleaded production (which helps determine butylenes use) can weigh heavily in butadiene producers' decisions to operate the dehydro units.

An even more important part of decisions on dehydro plants will be the selling price of butadiene. Butadiene prices have tumbled this year, from about 40 cents a lb to about 30 cents. At current price levels, industry sources are unanimous that operation of dehydro plants is out of the question.

Part of the reason for the slump in butadiene prices has been a rise in imports. Coming mainly from Western Europe, imports will top 700 million lb, possibly more than 750 million lb in 1982, way up from 1981. At these levels, imports will account for more than one fourth of U.S. demand, compared to less than 20% in 1981.

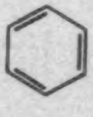
Imports are up because Western European ethylene plants continue to use largely naphtha or heavier feedstocks, which give large quantities of coproduct butadiene. (There are no operating dehydro butadiene plants in Western Europe.)

Since European economies are doing so poorly, butadiene is in unusually large surplus, and the only options are exporting or burning. Forced exports to the U.S. and elsewhere, if unprofitable, at least bring some income. Until business in Europe improves greatly, this butadiene export pressure will continue.

So in 1983, U.S. butadiene imports could match 1982 no matter what the U.S. economy does. And U.S. butadiene production will suffer accordingly. Chalk up a still-depressed 2.4 billion lb as the resulting outlook for butadiene output next year.

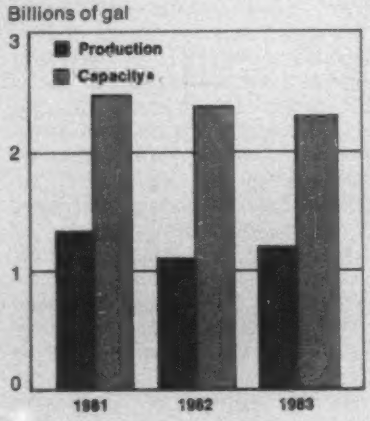
Key Chemicals

Benzene



- ***Demand off***
- ***Capacity down a bit***
- ***Prices flat***

PRODUCTION/CAPACITY



a First quarter; includes all sources.

HOW MADE

Separated from aromatics streams from oil refineries, steam-cracking olefins plants, and coking of coal; dealkylation of toluene

MAJOR DERIVATIVES (U.S.)

Ethylbenzene 50%, cumene 20%, cyclohexane 15%, aniline 5%

MAJOR END USES (U.S.)

Styrenic plastics 35%, phenolic polymers 20%, nylon 15%

FOREIGN TRADE

Exports—small, imports—more than 100 million gal in 1982

PRICES

List price $1.55 per gal

COMMERCIAL VALUE

$1.7 billion for production, 1982

Benzene beats out even butadiene for complexity among the basic petrochemicals. With four major types of supply sources, and half a dozen important uses, benzene producers and consumers have a lot of options, all massively influenced by the rise and fall of gross national product in expansions and recessions.

Benzene is produced by about three dozen companies. For many, their benzene business is minor in their total operations, sometimes a profit maker and sometimes a financial millstone. For example, petroleum refiners make benzene for gasoline and charge outsiders the basic cost of aromatics streams plus recovery and purification expenses for use in chemicals. Another supply group, chemical subsidiaries of oil companies, makes benzene when they steam-crack heavy feedstocks in olefins plants. The same subsidiaries sometimes dealkylate toluene to benzene. And other companies who coke coal make benzene as a by-product.

Some benzene producers also make derivatives, but a large number of derivatives makers buy benzene and then compete with benzene producers. Some of these nonbenzene producers make their entire business in benzene derivatives, but other companies couch these derivatives in a much bigger operation. To top it off, some benzene producers don't make enough to meet their own needs for derivatives, so they are also benzene buyers.

This complex makeup of the benzene community naturally makes exact data difficult. Production of benzene for 1982 is estimated at 1.1 billion gal but could range between 1.0 billion and 1.2 billion gal. Plant capacity has been falling during the year and will be about 2.3 billion gal as 1983 opens, down from 2.4 billion a year earlier. For 1982, the average plant operating rate will be only 45% of nameplate capacity.

But some benzene units, particularly dealkylation units, will have zero operating rates this year. Others, especially units extracting aromatics from refinery catalytic reformate and from pyrolysis gasoline made in steam-cracking olefins plants, will operate way above 45%. In addition, some coke oven operators, because of low related steel-making rates, have found that economics favor their selling light oil by-product containing benzene and not taking the added expense of operating their benzene separation units. So this benzene reaches the market even though the specific benzene units don't operate.

Dealkylation units, which could account for a quarter of U.S. benzene supply if economics favored their operation, are likely to remain down well into 1988, maybe the whole year. Toluene, separated from reformate and pyrolysis gasoline, has too high a value now to be dealkylated, since discounted benzene is only $1.50 a gal. Partly behind toluene's current value is a shift toward unleaded gasoline and increasing compression ratios in new car engines. These trends help to hold up toluene's value as an octane-boosting alternative to lead alkyls. Some counterpressure on toluene's octane-boosting value comes from competing octane boosters such as methyl *tert*-butyl ether.

A renewed rise in benzene's price will be slow in 1983. Demand will first have to pick up in derivatives. At the same time, derivatives' prices also will have to go up. But such increases don't seem likely soon, because the economy is giving little help to end uses such as packaging for polystyrene or adhesives for phenol derivatives.

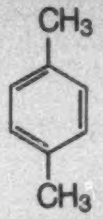
Styrene via ethylbenzene accounts for about half of benzene demand in the U.S. A small amount of ethylbenzene is recovered from mixed xylenes streams at oil refineries, but most is made by alkylation of benzene with ethylene. Dehydrogenation of ethylbenzene yields styrene. Styrene, in turn, goes into polystyrene, into polymers with acrylonitrile and butadiene, and into still other polymers. All of these polymers have been hit hard in the recession.

Of the other uses of benzene, cyclohexane, the product of simple hydrogenation, has been hit hardest. Since most cyclohexane goes into nylons, and the biggest nylon use is carpets, a recovery in consumer spending for housing and furnishings will be needed for cyclohexane's use of benzene to return to 1981 levels.

In short, a resurgence in benzene could begin in 1983, but it will take more than a year, possibly more than two years, for production to get back to 1979 levels.

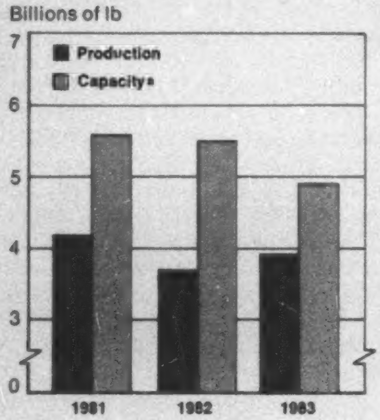
Key Chemicals

p-Xylene



- ***Output down***
- ***Capacity also down***
- ***Prices weak***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Separated from mixed xylenes made in oil refineries or in steam-cracking olefins plants

MAJOR DERIVATIVES (U.S.)

Dimethyl terephthalate 55%, terephthalic acid 45%

MAJOR END USES (U.S.)

Polyester fiber, film, and fabricated items (mostly bottles) almost 100%

FOREIGN TRADE

Exports—down to 600 to 700 million lb in 1982, imports—may reach 50 million lb

PRICES

List price 26.5 cents per lb

COMMERCIAL VALUE

$950 million for production, 1982

After the complications of the benzene market, *p*-xylene offers a certain relief in simplicity. But relief is the last thing *p*-xylene producers feel about their hard-pressed business.

Of the five large-volume basic petrochemicals, *p*-xylene is the only one with essentially one use—polyester. Other outlets exist such as herbicides and solvents, but these probably take less than 0.5% of U.S. *p*-xylene production. Clearly, as polyester goes, so goes *p*-xylene.

Such market singularity wasn't always bad. The boom in polyester a decade ago provided heady growth rates for *p*-xylene. But as often happens, these rates attracted too many producers, leading to overcapacity and downward price pressure. The result in the past few years has been a shakeout. Capacity has declined, notably in Puerto Rico with the failure of Commonwealth Oil and its associated chemical companies.

Late 1982 U.S. nameplate capacity for *p*-xylene is 4.9 billion lb per year, down some 900 million lb from peak capacity a few years ago. Operating rates have held roughly flat in spite of a 12% decline in 1982 production to 3.7 billion lb from 1981. This year, the operating rate will be about 67% of nameplate capacity and about 75% of capacity actually in operation.

Forecasts of *p*-xylene production are risky because companies underreport production and then revise totals later, adding as much as 500 million lb to initial estimates of the U.S. International Trade Commission. For the first eight months of 1982, official *p*-xylene production is running at about a 3.2 billion to 3.3 billion lb annual rate, well below industry sources' final estimates for the year.

Even with its reasonably good plant operating rates, *p*-xylene has felt downward price pressure this year from slumping demand. Prices are down about 5 cents a lb from a year ago, or more than 15%. Part of the reason is a plentiful supply at refineries, the result of declining demand in the competing gasoline market. Of course, gasoline can always soak up the basic xylenes streams at refineries quickly if demand turns around.

p-Xylene's price decline also reflects a slumping export market, which takes nearly 20% of U.S. production. Major *p*-xylene buyers in Europe and Japan have cut purchases. The resulting export price tumble has contributed to price cuts for U.S. sales.

Next year's outlook for exports naturally depends on the state of foreign economies. At this time, industry sources look for little improvement in early 1983. Inventories are still high even with the drop in 1982 production. Downstream, polyester fiber inventories also are high relative to sales. About the only favorable inventory level among *p*-xylene's end uses is in bottle resins, which have an expanding market.

The fibers market has been chaotic in 1982. Everything has seemed to go wrong. Exports declined as China chopped its purchases. In the U.S., fashion trends have worked against polyester in some uses as other fibers and leather gained in favor. At the same time, a decline in the cotton price has led to less use of polyester in blends.

Industry sources say there is no strong prospect for an upturn in fiber demand for polyester in 1983. But further decline also seems unlikely.

Any growth in *p*-xylene demand will come in two smaller uses—film and containers. Film use has been disappointing during much of 1982, but video cassette growth could add 100 million lb to *p*-xylene demand in 1983.

Container use of *p*-xylene almost surely will be up again in 1983, but growth will be slower than in 1982 unless the new 1-L bottles catch on fast. Such an upsurge is not expected earlier than the second half. At the moment, test marketing continues for 1-L and other smaller-sized bottles for soft drinks, other beverages, and food. Even with slower growth, bottles easily will add 100 million lb and possibly 200 million lb to *p*-xylene demand in 1983.

However, even with this bright new market in bottles, *p*-xylene can't overcome the continuing drag in the fibers business. After a decade of trouble, which analysts thought had effectively adjusted polyester fiber plant capacity and prices, polyester hit another unexpected shock this year. *p*-Xylene could not escape the results and will have to endure a renewed shakeout downstream.

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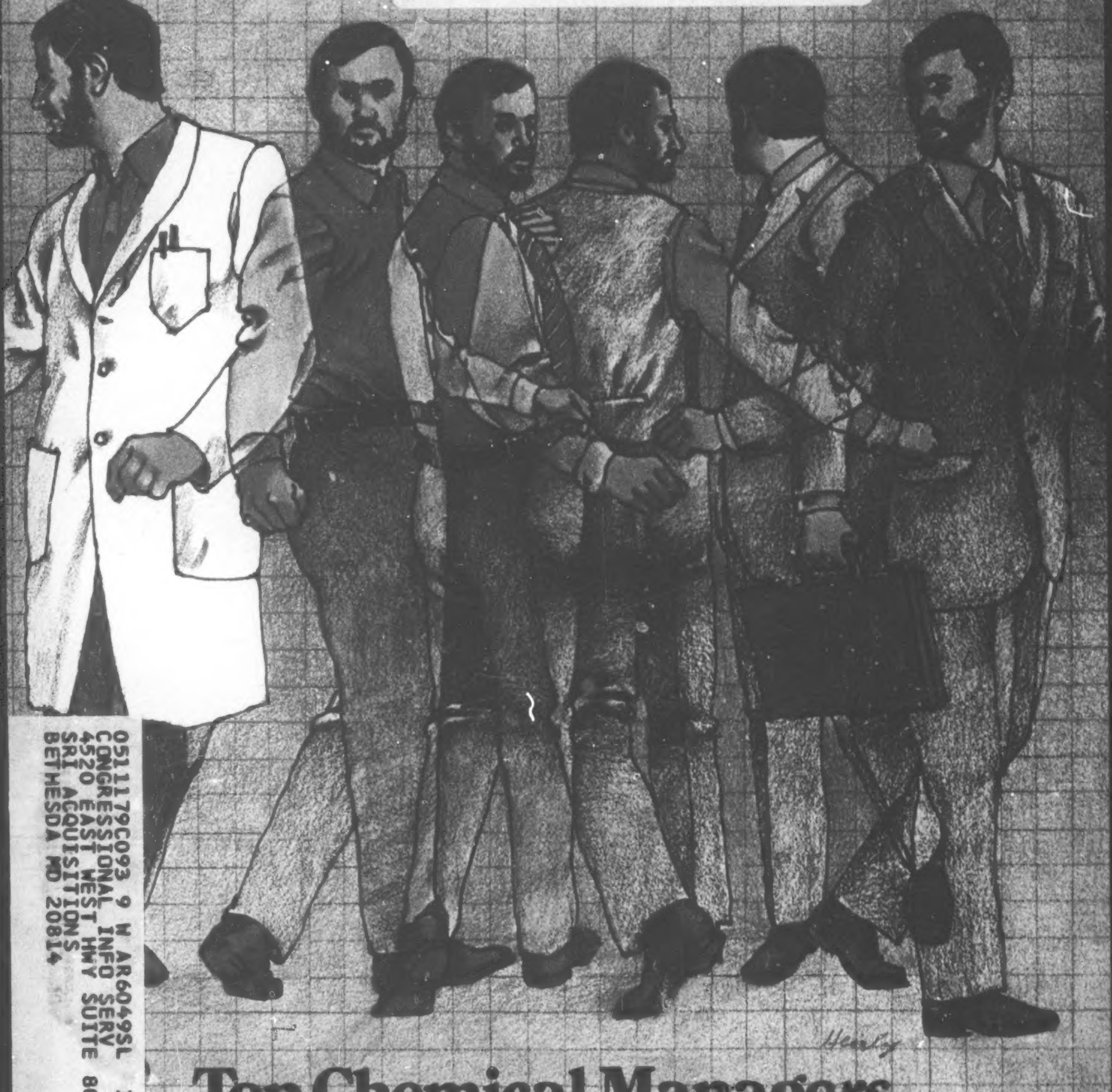

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Top Chemical Managers

More are coming from technical backgrounds

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Chemical productivity problems persist

Although current gains in labor productivity may suggest business pickup, total-factor productivity still has rough going

Chemical industry productivity—the measure of output compared to a given unit of input, such as wages, employee hours, or capital—has been going a rocky road.

After peaking in 1979, productivity in the chemical industry fell sharply in 1980, according to the American Productivity Center (APC), a Houston-based pioneer in measuring U.S. productivity. In 1981, productivity then rose, although solely on the strength of labor.

Labor productivity may well rise again in 1982 for the chemical industry, because as layoffs occur, efficiency tends to improve. Available government figures for all U.S. industry indeed show such a trend this year, with a notable 4.0% annualized gain in purely labor productivity in the third quarter.

However, even such a rebound in the chemical industry may not be enough to raise total-factor productivity (including factors for both labor and capital), according to APC. The reason is that output per unit of capital is expected to drop sharply because of low plant utilization. Capacity utilization in the third quarter dropped to 63% for the U.S. chemical industry, according to C&EN's latest survey (C&EN, Oct. 11, page 12), compared with plant use rates of 72% in the third quarter of 1981.

For 1981, APC's chemical industry total-factor productivity index rose to 101.3 (1977 = 100), up 1.7% from 1980. This index had dropped about 4.0% in 1980 from the 1979 index of 103.7. Comparable indexes for all manufacturing show a similar pattern, with a gain of 1.6% to 100.6 in 1981 from 1980 after a decline of about 2.4% from 101.4 in 1979. The previous peak in the total-factor productivity index for all manufacturing, as with the chemical industry, also occurred in 1979.

The APC productivity studies are broken down by major segments of the economy such as goods-producing and the services-producing sectors. Further breakdowns include farming, manufacturing, nonfarm manufacturing, and nonfinancial corporate business. Manufacturing is broken down into the various major industries such as chemicals, petroleum, rubber, and food. Nonfarm manufacturing includes such industries as mining, construction, transportation, and trade.

The chemical industry differs some from all manufacturing in its productivity components. In 1980, for example, labor productivity for the chemical industry declined more from 1979 than for all manufacturing, according to APC indexes. However, the recovery in 1981 for the chemical industry was larger than for all manufacturing, with the index rising from 102.0 to 105.3, or more than 3.2%, in comparison to a gain from 101.4 to 104.0, or nearly 2.6%, for all manufacturing.

Output per unit of capital for the chemical industry declined an average of 3.1% annually between 1979 and 1981; other industry groups had greater declines. For example, petroleum industry capital productivity declined to 92.3 in 1980 from 105.1 in 1979 and dropped further in 1981 to 85.9. That of primary metals fell from 100.7 in 1979 to 92.8 in 1980 and to 91.0 in 1981.

By contrast, indexes for ratios of capital-to-labor inputs compiled by APC have improved for all of the manufacturing groups. All manufacturing itself in this index moved ahead of the chemical industry in 1980 and remained ahead in 1981. The gains in the capital-labor ratio indexes show the importance of looking at both parts of the productivity output factors, says APC vice president Carl G. Thor. As for specifics, the chemical industry ratio grew in both 1980 and 1981, averaging a 3.5% annual change for these years. For the petroleum industry, this ratio grew substantially in 1980, rising to 16.2 from 99.7 in 1979, but fell off some in 1981 to 110.3. The primary metals ratio index also went up rapidly in 1980, reaching 111.1 from 97.0 in 1979, and continued to rise in 1981 to 114.6.

Other segments of the economy, except for farming and nonfinancial corporate business, turned down in total-factor productivity during the 1979–81 period. Total-factor productivity for farming rose from 105.7 in 1979 to 107.4 in 1980 and to 113.6 in 1981 as both labor and capital productivity improved. Of all the major segments, farming alone had better capital productivity in 1981 than it did in 1979.

Total-factor productivity of most industry groups in the nonfarm nonmanufacturing segment of the economy generally declined as well in the

Labor factor was main influence in chemical industry's 1981 productivity rise

					% average annual change	
Index, 1977 = 100	1981	1980	1979	1971	1979–81	1971–81
Total factor productivity						
Chemical industry	101.3	99.6	103.7	82.5	−1.2%	2.1%
All manufacturing	100.6	99.0	101.4	86.7	−0.4	1.5
Output per unit labor						
Chemical industry	105.3	102.0	104.8	77.2	0.2	3.2
All manufacturing	104.0	101.4	101.9	84.1	1.0	2.4
Output per unit capital						
Chemical industry	95.6	96.0	101.9	92.3	−3.1	0.4
All manufacturing	91.7	92.7	99.9	95.5	−4.2	−0.4
Capital-labor ratio						
Chemical industry	110.1	106.2	102.8	83.7	3.5	2.8
All manufacturing	113.4	109.4	102.0	88.1	5.4	2.8

Note: Data for years other than 1981 are revised to reflect revisions in various government data.
Source: American Productivity Center

1979–81 period. Among the few exceptions is the communications industry, whose total-factor productivity index rose from 107.9 in 1979 to 113.0 in 1980 and to 116.7 in 1981.

More detailed information on industry components is the current frontier at APC. This year APC worked out productivity ratios for such SIC categories as 331 (blast furnace, basic steel products), some human and pet food classifications, and 3079, miscellaneous plastics products. Data for 1980 and 1981 for these classifications have been extrapolated.

For the miscellaneous plastic products, mainly fabricated plastic materials (film and sheet, pipe, and the like), the extrapolated total-factor productivity index rose to 95.9 in 1981, above the 1979 level of 94.2 and well above the 1980 level of 91.9. As might be expected from results of the chemical and similar industries, the labor productivity index for this classification rose in 1981, reaching 107.2, up from 101.9 in 1980 and 99.2 in 1979. And, as expected, the capital productivity index reached 87.5 in 1981, up from the 1980 level of 84.4 but down from 90.7 in 1979.

Details of the APC input ratios for the miscellaneous plastic products classification show that value added rose in 1981 to an index of 110.0 from 105.0 in 1979 and 101.0 in 1980. Labor input, after falling to 99.5 in 1980, rose to 102.9 last year, still below the 106.4 of 1979. Capital, materials, and energy inputs all rose to well above the 1979 levels. The net result was the gain in productivity.

Even though productivity in the manufacturing industries generally declined as a result of the recession, the gain in labor productivity can be considered an indicator of underlying recovery, Thor suggests. Although the gains are not large, they do indicate basic business improvement. These modest gains come at the same time as relatively large increases in stock prices, which could suggest a stronger recovery will be coming.

So changes in labor productivity can be considered a leading indicator, Thor says. During a recovery, labor productivity improves faster at first and then slows as the recovery gets stronger.

Deeper into a recovery, capital productivity gains more rapidly. This is the result of a lower inventory-to-sales ratio and better plant operating ratios. Again, later into a recovery or perhaps early into a decline, the capital productivity growth slows or declines. ☐

CHECKOFF

NEW PLANTS

■ **Chromium dioxide**—Du Pont will begin second phase of expansion of Newport, Del., plant to make magnetic particles of this oxide for use in audio, video, and data storage tapes, to be completed by late 1983; undisclosed capacity will be doubled following this expansion and completion of first phase.

■ **Ethylene acrylic acid polymers**—Dow Chemical plans to spend about $50 million for new plant in Freeport, Tex., to make these resins used in adhesives, sizes, and coatings; plant will add about 60 million lb per year to Dow's capacity when on stream in early 1985.

■ **Industrial gases**—Air Products will build air separation plant to supply about 900 tons per day of oxygen and 400 tons per day of nitrogen to Texaco's refinery at Convent, La., at cost of $40 million. Oxygen will be supplied at 1100 psi, to partial oxidation unit to make hydrogen for converting petroleum residue to distillate fractions.

■ **Trichloroethylene**—Vulcan Chemicals, division of Vulcan Materials, plans to start engineering and design on unit to make this solvent at Geismar, La., plant; details on construction and size of facility are unavailable.

PLANTS COMPLETED

■ **Acrylic acid**—Badische has dedicated new world-size acrylic acid plant at Freeport, Tex., completing $120 million acrylic monomers complex. In March, rebuilt and expanded 2-ethylhexylacrylate unit was started up and in June new butyl acrylate plant began operations; total capacity of three units exceeds 350 million lb per year.

■ **Carbon fibers**—Union Carbide has begun production of polyacrylonitrile-based carbon fibers in Greenville, S.C., in 1 million lb-per-year plant. Company earlier had completed unit to make carbon fibers from petroleum pitch; two units cost more than $50 million.

■ **Fluoropolymers**—Allied Fibers & Plastics has started up Orange, Tex., plant making these resins used for wire and cable coverings. Of undisclosed capacity, plant augments production from company's Elizabeth, N.J., unit.

■ **Industrial gases**—Liquid Air Corp.'s industrial gases division has started up air separation plant in Anchorage, Alaska, thereby ending need for shipping liquid oxygen and nitrogen from out of state.

■ **Linear alkylbenzene**—Conoco Chemicals is starting up new unit at Lake Charles, La., with capacity of 150 million lb per year of this intermediate for detergents. Startup had been delayed from third-quarter 1982 to minimize construction costs.

■ **Monocalcium phosphate**—FMC Corp. has begun making and selling food-grade phosphate derivative in multimillion lb-per-year plant in Buffalo, N.Y., for use in baking materials and dry beverage mixes.

LABORATORIES

■ **W. R. Grace** will build $3.1 million fermentation pilot plant at its Washington Research Center in Columbia, Md., to develop line of pharmaceutical-grade amino acids.

■ **Badische** has opened new plasticizer technical center at company's Kearny, N.J., plant site, following relocation from Wyandotte, Mich.

■ **FMC Corp.** has dedicated $30 million agricultural research facility, located at chemical research complex near Princeton, N.J.

■ **IMCO Services,** division of Halliburton, will build 80,000-sq-ft building in Houston, Tex., as new technical center at cost of $7.5 million; completion due in September 1983.

■ **Warner-Lambert's Parke-Davis** research division has begun construction on $28 million preclinical laboratories building in Ann Arbor, Mich.; 95,000-sq-ft building to be opened in late 1984.

Chemicals' auto market could rebound

Long-suffering automobile business is finally heading up, says a new consulting study, and the surprise is that U.S. will lead the way

Has the giant auto market for chemicals been written down too soon? It has slumped all over the world since 1979 and has been part of chemical companies' standard explanation for their earnings woes this year. Not much more is expected in 1983.

For example, in a typical letter to stockholders last month, Celanese chairman John D. Macomber and president Allan R. Dragone say, "The demand for Celanese products is closely linked to sales of autos, housing, energy, and apparel. Although we have not yet had a real upturn in any of these sectors of the U.S. economy, we expect these industries and our own businesses to recover gradually in 1983."

Other chemical executives think the future for U.S. autos may be worse. Stauffer Chemical chairman H. Barclay Morley gives autos as a prime example of U.S. chemical markets moving offshore, to Japan in this case. He believes U.S. companies will have to follow or lose out (C&EN, Nov. 8, page 14).

But maybe not. A new study from consultants DRI Europe in London (part of Data Resources of the U.S.) concurs in ugly detail on the depressed current state of the worldwide auto business. But DRI winds up with considerable confidence for the industry from 1983 through 1986, especially in the U.S.

"The world motor industry has generally seen 1982 as yet another poor year," says DRI," with the anticipated recovery pushed back to the first half of 1983. There have been exceptions in Europe, where the industries of West Germany, Spain, and Sweden all have shown gains over their performance in 1981. The situation in North America continues to be desperately bad. In Japan the outcome for 1982 also will be poor as rising domestic sales will fail to compensate for a severe drop in Japanese exports."

Unfazed, DRI says the world auto business can "expect to do much better in 1983 and 1984 as economic conditions improve." Here's why:

- Deferred replacement demand. "The car populations of the world have aged significantly since 1979, and replacement of these cars will provide a clear boost to new car demand, particularly in North America."
- Rise in real consumer income over the next few years as inflation lags workers' pay.
- Stability in energy prices relative to inflation. There will be no new sudden rise or associated shortage.

These forces won't break auto companies' financial distress, DRI cautions, but still will push up car volume. Detroit and other motor capitals will remain poor because cash generation will fall far short of cash requirements.

Whatever, DRI comes up with some big numbers for recovery in autos by the mid-1980s. Despite a slow start in 1983, the U.S. will lead the pack by 1986 in both overall market growth and in home production. New car sales will pick up 14% in 1983 to 8.88 million from their extremely depressed rate of 7.78 million in 1982. By 1986, sales will be up 36% from 1982 to 10.61 million.

The U.S. production gain will be even better. DRI puts North American car production at 7.22 million next year, up 24% from 5.82 million in 1982. Production forecast for 1986 is 8.64 million, 48% higher than in 1982.

For U.S. gains to reach this size, the big loser would have to be Japan. DRI is not high on prospects for further inroads by Japanese cars in the U.S., predicting government protection to keep Japanese imports below 2 million units per year.

Quotas also will restrict Japanese exports to Europe and other markets, DRI says, and a steadily rising value of the yen will not help. Because of these and other factors, DRI foresees less than half the U.S. rebound in Japanese auto production in 1983—just 9%. By 1986, auto output in Japan will be up 20%.

In Europe, recovery also is due in most countries but at generally lower rates. The leading auto power there will remain West Germany, which survived a difficult 1982 with rising volume largely on the strength of new car development and exports. Overall, DRI views car sales in Europe up 6% in 1983 and 16% by 1986 from 1982. For production, the gains will be less, up 4% next year and 14% in 1986. □

U.S. auto market will grow faster than in other major economies . . .

Millions	New car sales			% change	
	1982	1983	1986	1982-83	1982-86
U.S.	7.78	8.88	10.61	14%	36%
Europe, total	9.71	10.32	11.24	6	16
West Germany	2.09	2.32	2.71	11	30
France	1.99	2.08	2.01	5	1
Italy	1.67	1.60	1.72	−4	3
U.K.	1.50	1.63	1.66	9	11
Japan	2.92	3.18	3.21	9	10

Source: DRI Europe

. . . and North American car output is due for an even sharper rebound

Millions	Car production			% change	
	1982	1983	1986	1982-83	1982-86
North America	5.82	7.22	8.64	24%	48%
Europe, total	10.04	10.43	11.40	4	14
West Germany	3.71	3.82	4.19	3	13
France	2.59	2.61	2.72	1	5
Italy	1.39	1.42	1.59	2	14
U.K.	0.89	0.87	0.90	−2	1
Japan	6.47	7.02	7.74	9	20

Chemical &
Engineering
NEWS

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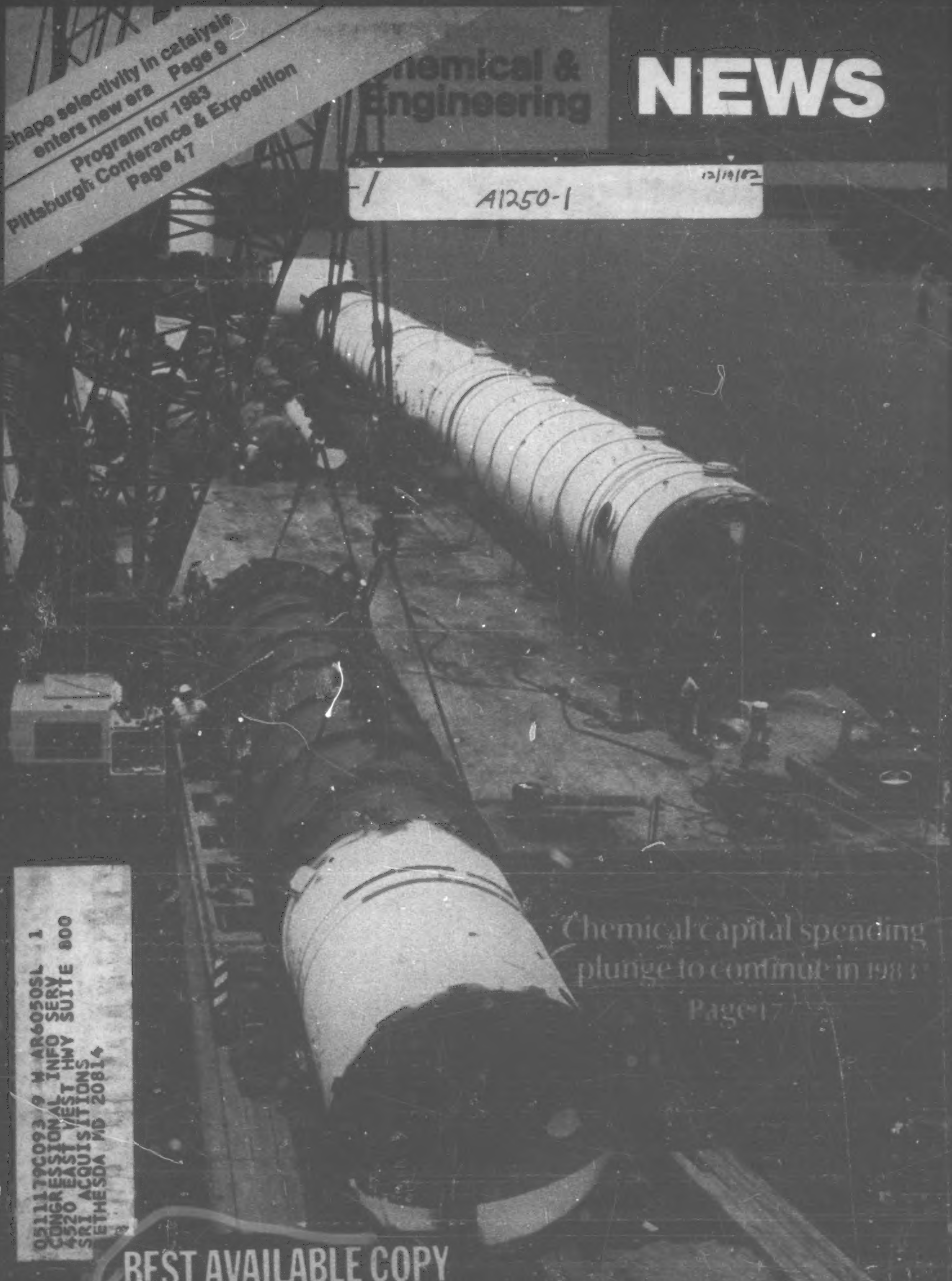

Shape selectivity in catalysis enters new era Page 9

Program for 1983 Pittsburgh Conference & Exposition Page 47

Chemical capital spending plunge to continue in 1983 Page 17

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Chemical & Engineering NEWS

Cover: Ethylene glycol plant's distillation column arrives by barge at Beaumont, Tex., from Guayanilla, P.R. PPG Industries and Du Pont jointly are rebuilding the unit for 1983 production

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News of the Week

- ***U.S. research and development*** *expenditures expected to reach $83.6 billion in 1983 according to Battelle Columbus Laboratories' annual forecast.* ***Page 6***
- ***U.S. economy may begin a slow recovery*** *in 1983, predicts a cautious majority of industrial purchasing agents.* ***Page 7***
- ***New artificial heart,*** *implanted in a human for the first time, is made of a durable plastic that is blood compatible.* ***Page 7***
- ***New research ideas*** *that could lead to significant technical innovation are being solicited for funding by DOE.* ***Page 7***
- ***Clayton F. Callis is elected chairman*** *of the American Chemical Society Board of Directors for his second term.* ***Page 8***

News Focus

- ***Shape-selective catalysts*** *offer chemists greater control of reactants and products; newest class of catalysts, aluminophosphates, now joins zeolites.* ***Page 9***

Business

- ***Capital spending among major U.S. chemical companies*** *reflects general economy, with substantial declines in outlays for 1983 and repercussions in other areas.* ***Page 17***

Government

- ***DOE's Division of Advanced Energy Projects*** *funds novel research projects related to energy, despite their high risk and recent plans to reorganize DOE.* ***Page 28***

Science

- ***Photoelectron microscopy,*** *extremely sensitive to the surface features of cells or membranes, is beginning to be used to study biological specimens.* ***Page 34***

Science Policy

- ***Regulation of cancer-causing substances*** *proves to be a controversial topic; C&EN presents policy experts' views contrary to those in an earlier article.* ***Page 35***
- ***Wide-ranging study of chemistry*** *is undertaken by a committee under the auspices of the National Academy of Sciences' Committee on Chemical Sciences.* ***Page 38***

Meetings

- ***The 1983 Pittsburgh Conference*** *& Exposition on Analytical Chemistry & Applied Spectroscopy opens March 7th in Atlantic City with more than 980 papers and almost 600 exhibitors.* ***Page 47***

BATTELLE PREDICTS 8% RISE IN R&D FUNDING

Expenditures for research and development in the U.S. will reach $83.6 billion in 1983, Battelle Columbus Laboratories says in its annual R&D forecast. According to Battelle economists Jules J. Duga and W. Halder Fisher, that amount represents an 8.2% increase from the $77.3 billion that the National Science Foundation estimates actually was to be spent for R&D in 1982.

More than half the increase will be absorbed by inflation, which Battelle estimates at 4.5% (for R&D) in 1983. Real growth in R&D will be about 3.5%, slightly higher than the average annual 3.3% increase for the past nine years.

Funding and performance patterns won't change much from previous years. However, for the second year in a row, industry R&D funding will exceed government support. Industry is expected to provide $41.4 billion, a 7.6% increase from 1982 and 49.6% of the 1983 total. The federal government is expected to provide $39.3 billion, an 8.8% increase from this year and 47.0% of the total. The rest will come from academic institutions ($1.8 billion, 2.1% of the total) and other not-for-profit organizations ($1.1 billion, 1.3% of the total).

Industry will continue to do most of the work. In 1983, Battelle says, R&D performance by industry is expected to come to $60.7 billion, or 72.5% of the total. In-house federal research will amount to $10.8 billion (13.0%). R&D by academic institutions will account for $9.7 billion (11.6%) and R&D performed by other not-for-profit organizations will come to $2.4 billion (2.9%).

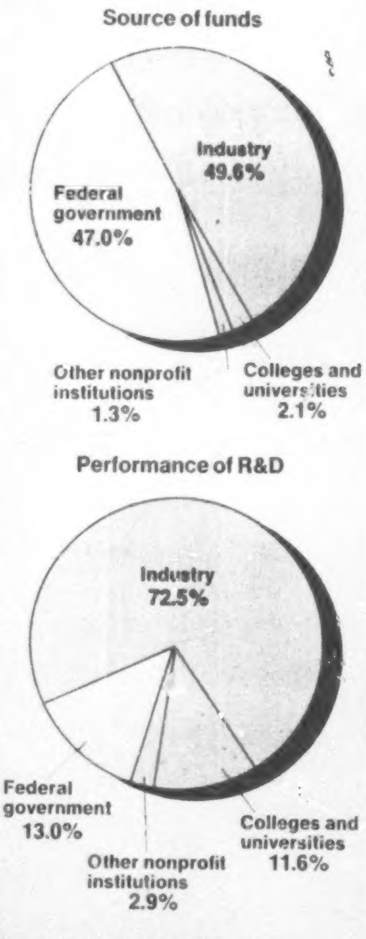
Federal funds support R&D performance in all four sectors, Battelle notes. About 25% goes for in-house work; almost 50% goes to industry; about 20% goes to colleges and universities; the rest, about 5%, goes to other not-for-profit organizations.

According to the forecast, four government agencies will account for 91.2% of total federal R&D funding in 1983: the Department of Defense (56.6%), the National Aeronautics & Space Administration (14.9%), the Department of Energy (10.4%), and the Department of Health & Human Services (9.3%).

Battelle says that increases in defense R&D spending are related primarily to the acquisition of major weapons systems. However, budgets also increased for space and general science programs. Space research has received a boost from the success of the space shuttle program. The potential use of the shuttle for economical orbital insertion and repair of satellites is seen as justifying continued support, the forecast notes.

However, funds for energy R&D will continue to decline, Battelle says, "since there is little evidence that energy will be perceived as a national problem requiring massive federal R&D support." Also, "less emphasis will be placed on 'soft' sciences, except those environmental, ecological, and socioeconomic investigations presently mandated by law."

R&D funding to reach $83.6 billion in 1983



Source: Battelle Columbus Laboratories

R&D will be heavily self-funded in the manufacturing industries, Battelle says, with, on average, only 32.2% of the total ($58.6 billion) coming from the federal government. In 1983, electrical machinery and communications will displace aerospace as the largest single sector of industrial R&D, with total funding close to $12.9 billion, 40.9% of which will come from the federal government. Total funds for aerospace R&D will amount to $11.8 billion, with about 80% of that amount coming from the federal government.

Other major sectors of industrial R&D include machinery ($9.05 billion total, 16.7% federally funded); autos, trucks, parts, and other transportation equipment ($7.19 billion, 14.4%); chemicals ($6.83 billion, 10.0%); professional and scientific instruments ($3.43 billion, 6.4%); and petroleum products ($2.47 billion, 12.5%).

Nonmanufacturing industries do relatively little R&D—only about $2.02 billion total in 1983, according to the forecast. Support for those activities will be divided almost equally between industry and the federal government.

In general, Battelle says, industry is taking over short-term R&D projects. It also is reacting to growing pressure from foreign technological competition. The forecast warns, however, that industry R&D commitments tend to lag a year behind cash flows.

Battelle also notes that, during the past few years, federal support has shifted toward more development and away from basic and applied research. If that trend continues, "the long-range consequences may pose significant problems in terms of the science base upon which economic vitality grows." That problem may be mitigated by a continuation of the recent resurgence of basic research support by industry. However, adds Battelle, the volatility of indicators that affect industrial R&D budgets—such as sales, profits, and cash flows—precludes stability for long-term planning. ☐

Chemical capital spending continues down

Budget plans for plants and equipment for major U.S. chemical companies fall again for 1983; economy is blamed

William J. Storck
C&EN, New York

Capital spending among U.S. chemical companies is having its own recession. Outlays are down 10.5% in 1982 from last year's level and will drop another 9.3% next year, according to C&EN's annual survey of leading U.S. chemical companies.

These declines are by far the biggest in at least 20 years. They confirm the universal impression that the chemical industry's investment in new plant and equipment—the largest use of company funds after ordinary running expenses and taxes—is in very weak shape. An upsurge in spending is nowhere in sight.

The trough in capital spending has weighty implications. It means, for example, continued poor prospects for engineering firms and the engineering job market and a continued pinch on cash flow for chemical companies.

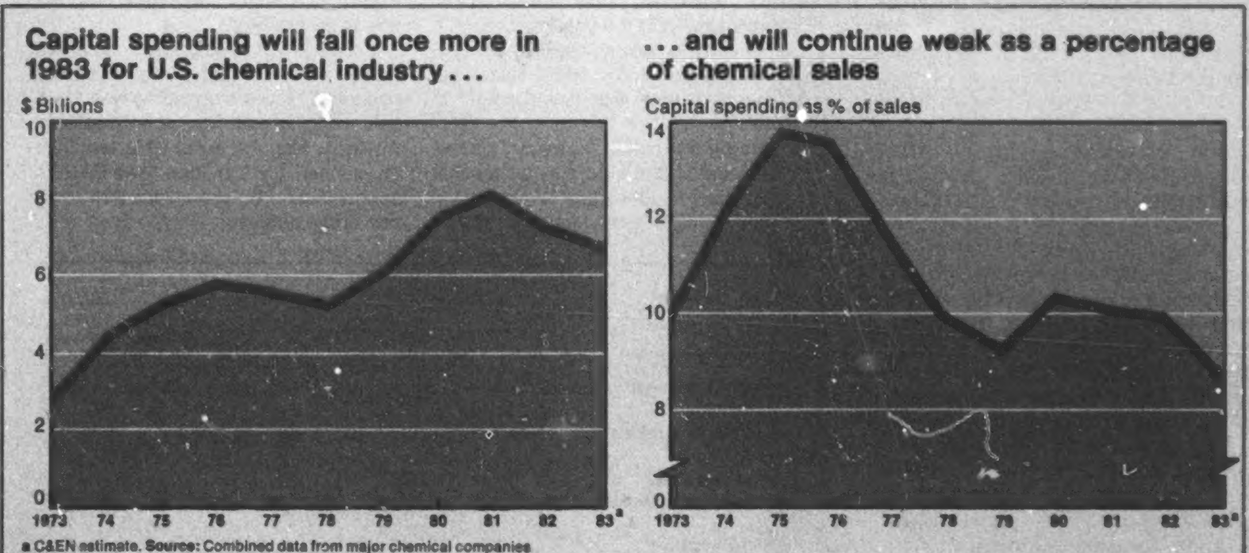
It is no wonder that capital spending in the industry has dropped. Some may even wonder that it hasn't fallen more. The reasons for the drop are simple: Earnings have plummeted as demand for chemicals, both in the U.S. and overseas, has fallen. Thus, return on investment at most chemical companies is down to the point where it is near or below reinvestment levels.

Few companies, if any, have reason to build plants. With reduced demand in 1982, practically 40% of the nation's chemical-producing capacity is lying idle. With this idle capacity and the outlook for only modest recovery next year, it may be 1984 or beyond before spending for new plant and equipment gets back to respectable levels.

The problems of capital spending are not confined to the chemical industry. Chase Econometrics says that investment spending in general will remain sluggish because of low operating rates and sharp declines in corporate profits. These are offsetting, according to the consulting firm, the favorable effect of recently enacted investment incentives. Chase Econometrics does not believe that investment will start to pick up until late 1983 when the general economy improves.

Charles Reeder, Du Pont's chief economist, says that despite favorable forecasts for some parts of the economy, the growth of total economic activity will be held down in 1983 by weakness in business capital spending and by net exports. He says that outlays on a constant dollar basis for new plants and equipment are de-

Outlays for new plant and equipment are down 10.5% in 1982 from last year



Capital spending will fall once more in 1983 for U.S. chemical industry . . .

. . . and will continue weak as a percentage of chemical sales

a C&EN estimate. Source: Combined data from major chemical companies

Capital spending in 1982 shows biggest drop in years

$ Millions	1983		1982		Worldwide					Change from previous year	
	Worldwide	U.S.	Worldwide	U.S.	1982 Planned[a]	1981	1980	1979	1978	1983	1982
Air Products	$ 275	$ 234	$ 347	$ 302	$ 400	$ 323	$ 364	$ 246	$ 200	−20.7%	7.4%
Allied	na	na	600	420	700	609	533	409	502	—	−1.4
American Cyanamid	na	na	180	126	185	181	196	235	251	—	−0.6
Celanese	248[b]	169[b]	275	187	400	414	253	245	248	−10.0	−31.3
Diamond Shamrock	360	324	540	486	540	521	387	266	319	−33.3	3.6
Dow Chemical	750	450	850	510	1000	1176	1184	1268	1075	−11.8	−27.7
Du Pont[c]	1358[b]	1154	1400	1190	1400	1500	1297	864	714	−3.0	−6.7
Ethyl	100	90	85	75	120	141	156	123	96	17.6	−39.7
W. R. Grace	495[b]	446[b]	625	558	800	685	658	514	313	−20.8	−6.0
Hercules	200	160	165	132	180	167	229	186	116	21.2	−1.2
Monsanto	700	616	615	541	660	668	781	566	460	13.8	−7.9
Olin	143[b]	135[b]	143	135	160[b]	186	172	161	163	0	−23.1
Rohm & Haas	135[b]	108[b]	125	100	na	182	93	68	66	8.0	−31.3
Stauffer Chemical	205[b]	195[b]	205[b]	195[b]	215	239	246	239	201	0	−14.2
Union Carbide	950[b]	627[b]	1150	805	1300	1186	1129	831	688	−17.4	−3.0
TOTAL FOR 15 FIRMS[d]	$5919	$4708	$7305	$5762	$8060	$8158	$7650	$6141	$5362		
ANNUAL CHANGE[d]	−9.3%	−9.7%	−10.5%	−6.7%	−1%	7%	25%	15%	−5%		

a Earliest estimate. b C&EN estimate. c Excludes Conoco. d 1983 excludes Allied and American Cyanamid. na = not available.

clining sharply now and this situation will continue through most of next year, no matter how low interest rates fall. Part of the decline is linked to reduced investment in the energy area and part reflects low capacity utilization rates for manufacturers. According to Reeder, several quarters of strong business activity will be required before a turnaround in capital expenditures even can be considered.

Undoubtedly, what is true for the general economy also is true for the chemical industry in this instance. As the economy drags and as the industry matures, it may be a long time before chemical companies experience the 25% annual increase in capital spending they did in 1980 or even the 15% rise in 1979.

In 1982, capital expenditures among the 15 leading chemical companies surveyed by C&EN will fall about 10.5% from 1981 to $7.31 billion. The downward adjustment of spending during the year from what was originally forecast by the chemical companies is quite indicative of a deepening recession. The 15 firms originally had forecast that capital spending in 1982 would be down 1.2% from 1981 to $8.06 billion. However, as the year progressed, budgets were revised until actual spending will come in at about 9.4% below the original forecast. It is not unknown for actual spending to come in below the first optimistic forecasts, but a change this great is unusual.

Among the companies surveyed,

West German spending in the U.S. will be flat

One of the largest blocks of chemical capital spending in the U.S. controlled from abroad is from West Germany. Capital spending in the U.S. by the three largest West German chemical companies, unlike their U.S. counterparts, will be down only slightly—less than 1%—in 1983. However, one company's spending will be down considerably, one up substantially, and one will be flat.

Combined capital spending in the U.S. among the three will total about $361 million, a decline of just 0.8% from 1982. However, only BASF North America reflects the general picture. It is planning to hold its capital spending flat at $160 million in 1983. This is the same as it says that it will spend in 1982.

On the down side, however, American Hoechst, the U.S. arm of Hoechst A.G., plans to spend just $71 million in 1983, off 22% from this year. Mobay and other Bayer-owned U.S. subsidiaries plan to spend $130 million in the U.S. next year, up 15% from 1982.

The spending decline for 1982 from the year before, among the three companies, far outpaced that for U.S. chemical companies and there were big drops for all of the companies. Spending among the three totaled $364 million in 1982, down 33.6% from 1981.

By far, the worst case was Mobay, whose outlays dropped 54.4% from 1981 to $113 million. BASF was second with a 20% drop to $160 million, and American Hoechst's spending dropped 9% to $91 million.

For 1982, all three of the companies came in below original budgeted capital spending. Mobay's spending was 27% below original estimates of $155 million. American Hoechst spent 23% less than its planned $118 million. And BASF's spending fell 20% below the $200 million first estimated.

U.S. subsidiary (parent)	Capital spending in U.S. ($ millions)						Change 1982–83	Average annual change 1978–82
	1983[a]	1982	1981	1980	1979	1973		
American Hoechst (Hoechst)	$ 71	$ 91	$100	$100	$189	$105	−22%	−4%
BASF North America (BASF)	160	160	200	200	136	118	—	8
Mobay and other subsidiaries (Bayer)	130	113	248	220	150	119	15	2

a C&EN estimate.

the largest year-to-year drop in capital expenditures was at Ethyl, where spending in 1982 will be about $85 million. This is 39.7% below 1981 spending.

Two other companies—Rohm & Haas and Celanese—spent more than 30% less in 1982 than in the previous year. At Rohm & Haas, capital spending in 1982 was $125 million, a 31.3% decrease from 1981. Celanese spending dropped 31.3%, too, to $275 million.

The biggest dollar-volume drop was for Dow Chemical, whose capital spending in 1982 will total about $850 million, off 27.7% from 1981.

Only two companies increased their capital spending this year. Air Products' spending on new plant and equipment for its fiscal year ended Sept. 30 rose 7.4% from fiscal 1981 to $347 million. And Diamond Shamrock's capital spending this year will increase a modest 3.6% to $540 million.

For next year, chemical capital spending continues to look bleak. C&EN's survey shows that chemical companies will spend about 9.3% less on new plants and equipment than they did in 1982.

Some companies are planning big cuts. For example, Air Products, which had a 7.4% increase in 1982, says that capital spending in 1983 will be about 20.7% lower, at $275 million, than this year's $347 million.

Diamond Shamrock, the other company with an increase in 1982, is planning a spending cut of 33.3% in 1983 to about $360 million.

Preliminary estimates are that W. R. Grace will cut its capital budget by about 21% with spending of less than $500 million next year. Union Carbide will spend about $950 million next year, based on preliminary estimates, down 17.4% from this year. Other companies cutting their budgets next year include Celanese, Dow Chemical, and Du Pont.

If it is not just an initial flash of optimism, there are some companies that are planning hefty increases in capital spending in 1983. For instance, Hercules has budgeted to spend about $200 million, up 21.2% from 1982. Ethyl says that its capital budget will be about $100 million, up 17.6% from 1982. Monsanto will spend $700 million next year, an increase of 13.8% from this year. And Rohm & Haas says that spending will be up, but doesn't indicate by how much. C&EN estimates that spending at the Philadelphia-based company will be 8% above 1982's $125 million.

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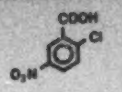
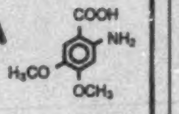


2-Chloro-5-nitrobenzoic acid

4-Nitroethylbenzene

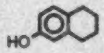
NEW



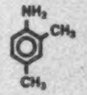
2-Amino-4,5-dimethoxybenzoic acid
(6-Aminoveratric acid)

2,3-Benzofuran
Coumarone

NEW



6-Hydroxytetralin



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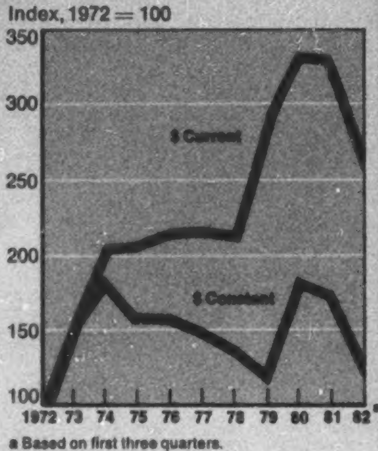
Capital appropriations have plummeted



a Based on first three quarters.
Source: Conference Board

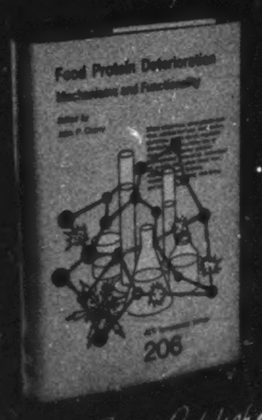
Most of the companies say that U.S. spending will take about the same percentage of total capital spending next year as it did this year. Combined capital spending overseas will be about $1.20 billion for 13 of the 15 companies this year, compared with about $1.31 billion in 1982. This is about 21% of worldwide spending for both years.

C&EN's finding in its survey that future capital spending will decline is supported in part by the Conference Board, except the New York City-based business group's figures are even more dismal. In its third-quarter report on capital appropriations (monies to be spent in the future), the Conference Board found that through the first three quarters of 1982, appropriations for the broad category chemicals and allied products fell 26.5% from the first nine months of 1981 to $6.88 billion. The third quarter alone was even worse, with appropriations dropping 29.7% to $2.38 billion.

On a constant-dollar basis, the picture is even worse. For the first three quarters this year, appropriations, expressed in 1972 dollars, have dropped 30% from the first nine months of 1981 to $3.46 billion. Third-quarter appropriations are down 32.3%, falling to $1.19 billion. On an annualized basis, it looks like 1982 will be the worst year for constant-dollar appropriations since 1972.

Thus, if the Conference Board's figures are correct, the pundits are correct and capital spending is going to stay depressed for some time to come. □

Food Protein Deterioration
Mechanisms and Functionality



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Updates and expands the state of the art of protein deterioration. Studies physicochemical changes of proteins during genetic and physiological processes. Confronts the issue of nutritional quality and bioavailability of structurally deteriorated or modified proteins.

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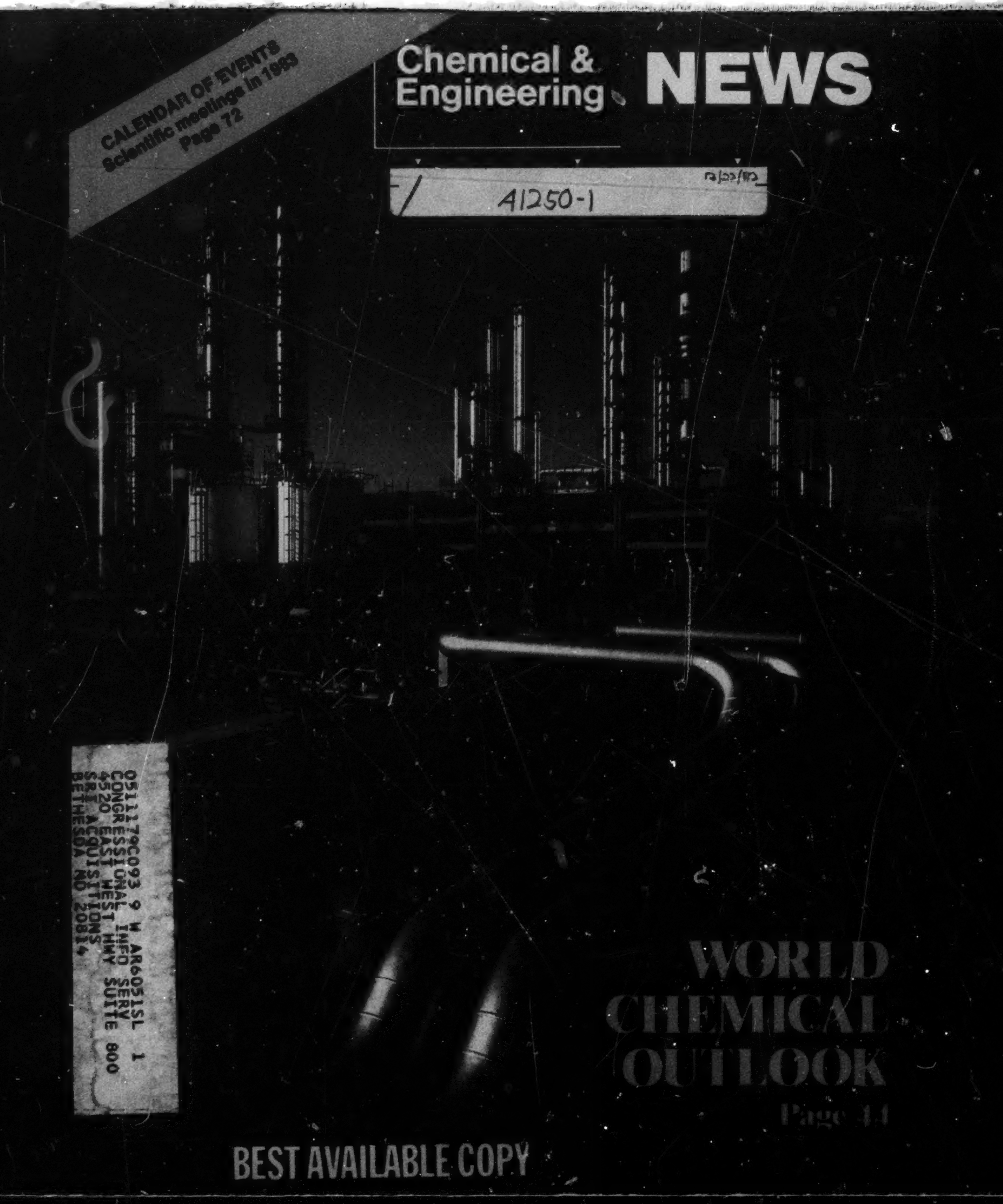

WORLD CHEMICAL OUTLOOK

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Chemical & Engineering NEWS

Cover: Aromatics expansion completed this year by Badger Ltd. of London (part of Badger of the U.S.) for Petrogal at Porto, Portugal

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Slump hit major solvents hard this year

Acetone and methylene chloride production may recover a bit in 1983, but synthetic ethanol may be hurt even more by competition

Bruce F. Greek
C&EN, Houston

U.S. solvents producers never had illusions about 1982, but the results were much worse than expected. Looking generally for flat to slightly falling production this year, producers of the three major solvents—acetone, ethanol, and methylene chloride—detailed in the following pages, now find combined output down 15% from 1981 and 28% from the peak year of 1979.

The outlook finally seems to be changing for the better. Production may turn up 5 to 10% in 1983 for acetone and methylene chloride. However, that still will not match 1981's output, let alone 1979's. Pessimists hold sway for synthetic ethanol, forecasting 1983 production even lower than in 1982 because of its problems of competing with fermentation ethanol.

Doubt clouds all of these forecasts. Industry sources are dubious, for example, that their earlier forecasts for 1983 production will be met, now that 1983 is getting close. 1984 now is widely regarded as the year in which acetone and methylene chloride production will again equal output in 1981.

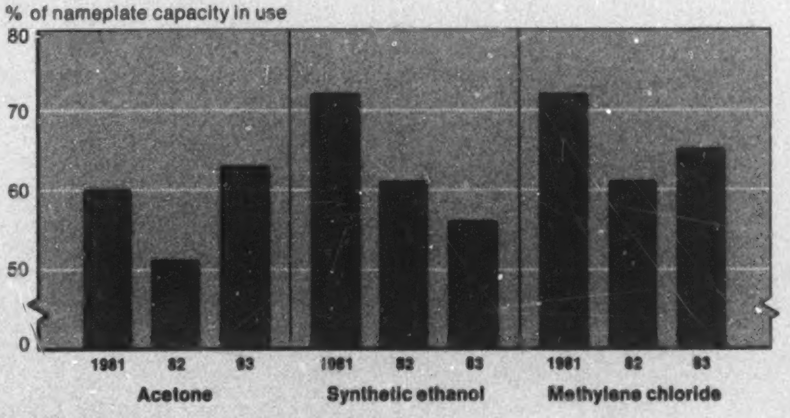
Ethanol's fortunes could continue to diverge from the others. Competition from fermentation ethanol, either made in the U.S. or imported, could lengthen synthetic ethanol's downtrend for years ahead. A possible break in the trend could occur if economic recovery in the U.S. proves more robust than now forecast.

The ethanol competition continues to be complicated by a background interplay of raw material hydrocarbon and grain costs. If real costs of grain, mostly corn, and other sources of fermentation ethanol keep heading down, then synthetic ethanol will become slowly less competitive as feedstock ethylene prices hold or rise. The underlying force on ethylene is that its own raw material light hydrocarbon prices are holding or rising with the slow deregulation of natural gas.

Key Chemicals

Unless unusual weather plays a role, corn prices are not expected to rise much for at least the next year because of surpluses on the farm. Hence, fermentation ethanol likely will have less raw material cost pressure than will synthetic ethanol. The tax incentives for use of fermentation ethanol in its main intended market in fuels also could decline, putting pressure on producers to sell it wherever they can. The alternative is largely industrial solvent uses, one of the main preserves of synthetic ethanol.

Even with some upticks, plant use will stay low in 1983



Sources: Industry, C&EN estimates, International Trade Commission

The other two solvents in this group have the same hydrocarbon cost pressures as does synthetic ethanol. This pressure includes the large energy cost increases in making constituent chlorine. Such cost pressures in the U.S. are likely to continue even though world prices for crude oil may slip for some time to come.

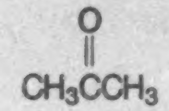
In addition to bringing cost pressures from raw materials and energy, the decline in solvents demand hurts producers' plant efficiencies and incomes. In 1982, sales value of these three major solvents will total about $950 million, down 14% from $1.1 billion in 1981.

If inflation were taken out of the data, producers of these solvents would find 1982 sales are down even more from 1981. Volume and price increases expected during 1983 would bring up the current-dollar sales for acetone and methylene chloride but probably not for synthetic ethanol. This trend could continue further in the 1980s: Inflation-adjusted sales could do little more than stand still. If, as widely forecast, imports begin to take a share of the U.S. market and exports dry up, sales could decline in both real and current dollars.

This uninviting prospect suggests an accompanying decline in plant capacity. Eventually, according to industry sources, solvents most likely will get the same capacity-cutting combination now occurring in other chemicals—long-term idling of some units and actual scrappage of others. However, unless some unusual tax incentives come along, such as faster depreciation on new units, sources suggest that outright scrappage will be low even with very low operating rates. Unused plants simply will be allowed to sit. Then the question of how much of total capacity is really operable will become much more difficult, even for producers.

Key Chemicals

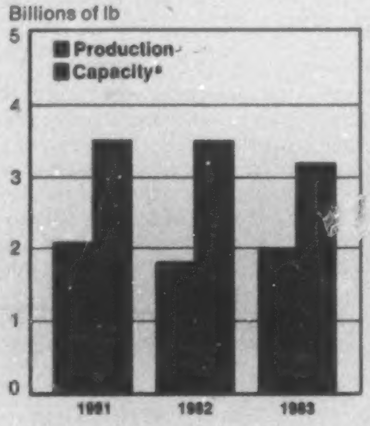
Acetone



$CH_3\overset{\overset{O}{\|}}{C}CH_3$

- ***Demand down***
- ***Capacity reduced***
- ***Prices discounted***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Coproduction with phenol by oxidation of cumene; dehydrogenation of 2-propanol

MAJOR DERIVATIVES (U.S.)

Methyl and other methacrylates 30%, methyl isobutyl ketone 10%

MAJOR END USES (U.S.)

Solvents, alone or as derivatives 60%; fabricated plastics 30%

FOREIGN TRADE

Exports—declining to about 125 million lb in 1982; imports—negligible

PRICES

List price 29 to 31 cents a lb; discounting widespread

COMMERCIAL VALUE

$500 million for production, 1982

Acetone dissolved into recession this year even worse than producers feared. The product's strong ties to consumer demand—and hence to the ups and downs of business cycles—come through its use as a solvent for coatings and as an ingredient of acrylic polymers. Assuming a slow recovery from the recession in 1983, the outlook for this material similarly is a small bounce. As might be expected, a return to 1979's peak production levels will take at least until 1984.

Acetone is both coproduced with phenol and made independently from 2-propanol. As a coproduct, acetone production depends strongly on demand for phenol. And phenol, whose major use is in adhesives for plywood, has been shaken badly by the decline in housing production.

Even so, demand for phenol apparently has held up better than for acetone. Telling evidence of surplus acetone comes from list-price cuts following earlier temporary voluntary allowances and from temporary shutdown of some of the 2-propanol-based units. Acetone pricing remains fragile, and discounting continues even after the list price decline.

Both U.S. and export demand for acetone have declined in 1982, leading to an overall production slump of about 15% to about 1.8 billion lb from over more than 2.1 billion lb in 1981. Some inventory cutting also has occurred this year, so consumption might turn out to be a bit higher than production as in a great many other commodity chemicals.

This inventory cutting could be a blessing, say some industry sources, if it spurs production ahead of demand in 1983. For this reason, plus an expected general recovery in acetone uses as the economy improves, a production rebound of about 10% to 2 billion lb or so seems likely in 1983.

Plant capacity for acetone has dropped in 1982. The main influence was Allied's decision not to rebuild completely the capacity at Frankford, Pa., damaged by fire last spring. The resulting capacity decline is not quite 10% of the former industrywide total. This plant is one of the coproduct operations making acetone and phenol from cumene. Partly offsetting this capacity loss has been startup of new phenol-acetone capacity at General Electric in Mt. Vernon, Ind.

Nameplate capacity for acetone now totals about 3.2 billion lb a year. So if 1982 production comes to the consensus level of 1.8 billion lb, the average operating rate will be a very poor 56%.

However, considerable capacity currently is shut down. Some of this capacity is cumene-based, but more of it is based on 2-propanol. Given the relative rise in value of propylene compared to other hydrocarbon raw materials, 2-propanol-based acetone must have difficulty competing with cumene-based acetone. It doesn't help matters that cumene-based acetone is forced on the market by phenol demand.

Estimates of shut-down capacity vary from 10 to 20% of the nameplate total or 300 million to 600 million lb per year. If, say, 500 million lb of acetone capacity do not operate at all this year, the remaining plants then have run at an average rate of 67%—still not good, but closer to plant-use levels in other commodity chemicals.

Whether producers restart these shut-down plants depends on the nature of any recovery in 1983. Current thinking has solvent markets for acetone swinging up a bit faster next year than will the housing markets for phenol. Hence, to meet solvent demand, more of the "on purpose" acetone will be needed via 2-propanol.

Acetone's chemical uses, the most important being methyl methacrylate, are expected to recover a bit faster than will the general economy because most of these uses sport predicted growth rates higher than for gross national product. But these chemical outlets possibly may not push up as fast as will the solvent markets. Chemical uses are generally well established, with trends changing more slowly than in the more volatile solvents. Solvents go into many small-volume areas, some of which grow and die rapidly.

For 1983 then, acetone will not fully recover from its sharp 1982 decline. And after several years below previous production highs, the likelihood grows that some small, currently shut-down plants will be scrapped.

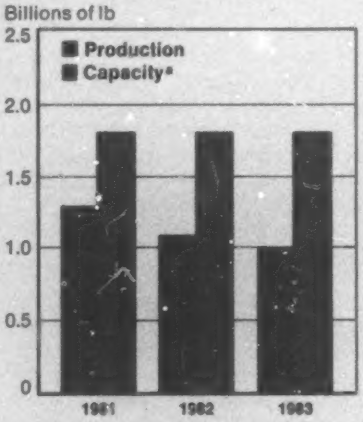
Key Chemicals

Ethanol

CH_3CH_2OH

- ***Demand down***
- ***Capacity cut possible***
- ***Prices soft***

PRODUCTION/CAPACITY



a Synthetic only as of first quarter.

HOW MADE

Hydration of ethylene

MAJOR DERIVATIVES (U.S.)

Acetic acid (vinegar) 10%, esters 10%, ethers 5%

MAJOR END USES

Solvents 55% (85% including derivatives), food 10%

FOREIGN TRADE

Exports—holding at 60 million lb in 1982; imports—may reach 175 million lb, including some fermentation ethanol

PRICES

List prices $1.85 to $1.97 per gal; discounting widespread

COMMERCIAL VALUE

$325 million for production, 1982

Synthetic ethanol's private recession in the U.S. probably will keep right on going in 1983. Whether this commodity's difficulties eventually will become as bad as those of fermentation ethanol 25 to 30 years ago, when it was almost wiped out by synthetic ethanol, no one yet predicts.

But it is clear that production of synthetic ethanol has continued to drop in 1982, descending perhaps more than 15% from 1981 to 1.1 billion lb. In 1983, industry sources forecast another drop to about 1.0 billion lb. Later on, production could level off, but a pack of uncertainties makes any such forecast shaky.

Plant capacity for synthetic ethanol continues to hold at about 1.8 billion lb a year. Of this nameplate total, a bit more than 20% is shut down, with prospects of restarting iffy. In addition, something less than 10% of total capacity goes largely to captive uses.

The remaining two thirds of capacity, some 1.2 billion lb or a bit more, supplies the merchant market. The merchant plants are running at relatively high rates among big-volume chemicals. For plants actually operating, 1982 production of 1.1 billion lb means a current operating rate possibly close to 80%. On paper, of course, the use rate drops to just over 60% of all available capacity, including units that are shut down.

The same problems, only worse, that prompted the decline in production of synthetic ethanol in 1982 are likely to stick around in 1983—the slump in the economy and slow market inroads by fermentation ethanol. Solvent uses of ethanol are so diverse that in general they follow the overall economy. Since these product chains eventually reach consumer goods such as cosmetics and toiletries, a recession such as in 1982 is a big blow.

Fermentation ethanol's influence on synthetic ethanol is complex and growing. Until quite recently, the general high quality and uniformity of synthetic ethanol gave it control of markets that fermentation products couldn't touch. However, recent improvements in the quality of some fermentation ethanol have gained producers the nod from some formerly uninterested customers.

Even with the added costs of quality improvement, fermentation ethanol still can sell below list prices for synthetic ethanol. As a result, pricing of ethanol has become chaotic, according to industry observers. Prices cover quite a range in different parts of the country, depending on real or apparent influences of fermentation material. Reported discounts vary from a cent or two per gallon to 10% or more.

This overhang of fermentation ethanol depends on sharply varying conditions such as the current capacity excess in its primary market in fuels. Fuel uses such as gasohol, in turn, are influenced by economics. For example, states with some kind of tax exemption on ethanol for fuel use are taking another look, especially with a potential increase due in the federal fuel tax. Most states are short of revenue, and some have been forced to shift general funds to highway use because fuel taxes haven't kept up with highway costs.

Economics also will be influenced by possible imports of fermentation ethanol from countries with surpluses, such as Brazil. If imported ethanol were landed at a cost of $1.00 per gal, well below domestic selling prices, then U.S. producers of fermentation ethanol would increase their efforts to sell into the alternate industrial markets held by synthetic ethanol.

Methanol also enters the future fuels picture. It may gain a market as a substitute for ethanol in gasoline blends because its price is half or less. Any such development also could push more fermentation ethanol into synthetic markets. The size of the methanol fuel market is difficult to estimate, according to industry sources. But as long as overall methanol demand is weak, this interplay with ethanol in gasoline should be expected, even though there is concern about the damaging effect of methanol on engine parts.

The prospects then in synthetic ethanol are for slow erosion of traditional markets, continuing effort by producers to stay ahead of fermentation ethanol in quality, and little change in the nonfuel use pattern. Fermentation ethanol producers won't have everything their way, either, with capacity ballooning, government subsidies possibly lowering, and imports looming as competition.

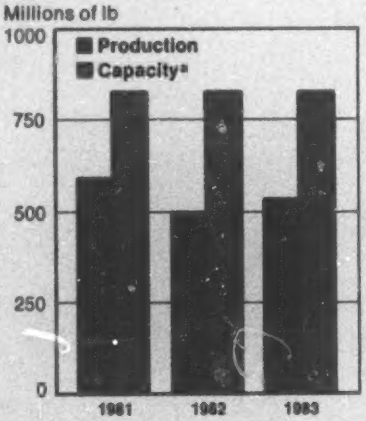
Key Chemicals

CH_2Cl_2

Methylene chloride

- ***Production down***
- ***Capacity excessive***
- ***Prices low***

PRODUCTION/CAPACITY



[a] First quarter maximum, varies with product mix.

HOW MADE

Chlorination of methane; hydrochlorination of methanol, then chlorination of methyl chloride

MAJOR DERIVATIVES

None of any size

MAJOR END USES (U.S.)

Paint remover 30%, aerosol propellants 20%, degreaser 10%

FOREIGN TRADE

Exports—about 40 million lb in 1982; Imports—about 30 million lb

PRICES

List price 26.5 cents a lb; discounting widespread

COMMERCIAL VALUE

$125 million for production, 1982

Methylene chloride has properties that would seem to give it strong demand—high solvency, low toxicity, inflammability, and low corrosiveness. Unfortunately, 1982 has turned out to be another in a series of poor years.

Estimates of 1982 production of methylene chloride range more widely than for most other big-volume chemicals. Output is estimated anywhere from 480 million to 540 million lb, down 9 to 19% from the final International Trade Commission figure of 592 million lb in 1981.

Production is hard to pin down because of methylene chloride's diversity of uses and the interplay of chemical reactions involved in making several chlorinated methanes in the same plant. A good guess is that production of methylene chloride will be down 15% this year from 1981, close to 500 million lb after a poor fourth quarter.

Similarly, plant capacity for methylene chloride varies considerably because producers can change product mix of the four chlorinated methanes by changing process conditions. Since methylene chloride is second in the product slate, producers can recycle it to increase output of the heavier chloromethanes, chloroform and carbon tetrachloride, to meet market needs. Sources' estimate of 825 million lb for nameplate capacity probably is close to the maximum. A minimum capacity might be as low as 700 million lb.

Production of 500 million lb in 1982 would put plant use at about 60% of the maximum figure, down from more than 70% in 1981. Most likely, however, the real operating rate this year will be higher than 60% because of product mix decisions lowering actual capacity for methylene chloride.

This low operating rate has hurt prices, as expected. In a year's time, list prices have dropped more than 10% to 26.5 cents a lb from 30.5 cents. Producers cut prices to bring list quotes closer to actual selling levels. The gap has not fully closed, however, according to industry sources. Discounting still goes on, especially by sellers of imported material and U.S. producers who must compete with imports.

To some extent, low prices for raw material chlorine helped producers hang on to any profit margins earlier in the year. Now that chlorine prices have begun to rise, the squeeze is really on for methylene chloride. The chlorinated methanes might set price increases as 1983 begins because producers may have no other option except to close up. Variable costs, chiefly raw materials, in making methylene chloride and other chlorinated methanes make up 70 to 80% of total production costs, leaving little room for savings when raw materials prices increase.

Even with possible price hikes coming, methylene chloride is expected to rebound because it has a number of uses for which it is the best material for these costs. New uses develop occasionally, including substitution for other solvents. But neither such developments nor the recession in established markets is expected to change significantly the overall use pattern.

Some uses, such as aerosol propellants, are growing faster than others such as paint remover formulations, which have been hit by the recession. Industry sources are reluctant to predict the year, but most agree that aerosols will supplant paint removers as the largest use area. The shift away from aerosols containing fluorine atoms obviously helps methylene chloride.

Aerosols have another plus as an outlet for methylene chloride in that a few large packagers of aerosol products account for a substantial share of total demand, affording high-volume sales. In contrast, paint removers are more often formulated by small companies, who are supplied by chemical distributors. Distributors, in turn, are a large source of sales for primary producers of methylene chloride. Distributor competition tends to vary a lot with services desired by these small users, thereby often unduly influencing sales of methylene chloride.

Other sizable uses of methylene chloride such as degreasing are more industrially oriented and have been affected strongly by the recession. Recovery in demand here depends on the strength of recovery in the economy.

For 1983, the overall expectation is that methylene chloride should experience a modest recovery, 5 to 10% above 1982 production but still under 1981 production. Complete recovery will take longer.

Special Report

WORLD CHEMICAL OUTLOOK

The malaise that was widespread throughout the world's chemical economy a year ago has become pandemic as 1982 winds down. With demand sapped by global recession, production of chemicals has been cut back drastically across the industrialized world, and producers increasingly find themselves strapped financially.

In the U.S., output has been stumbling for the past two years. Plants are running far below capacity, and profitability is the skimpiest in recent memory.

Western European producers, also plagued by plant capacity, far in excess of any foreseeable demand, are desperately seeking ways to retrench, trim costs, and reduce their burdensome load of debt. In Japan, an industry that has lost its competitive edge likewise is looking for ways to slim down and consolidate its operations. And world trade in chemicals, after surging in the 1970s, is down for the second year.

Now that the business recovery many chemical producers confidently had looked for during the latter months of 1982 has proved to be a will-o'-the-wisp, hopes are riding on a revival sometime during the year ahead. But the current winter clearly will be bleak. And conclusive evidence that the worst is over has yet to appear.

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Business will improve next year, but the recovery may be sluggish

UNITED STATES

Chemical producers look to higher consumer spending to revive their severely depressed production and profits

David M. Kiefer, C&EN Washington

Last year's consensus forecast for the chemical industry in 1982—that after several months of slack business, recovery clearly would be evident during the second half—may still prove accurate. It will, that is, if one reads the forecast to mean the second half of 1983, rather than that of 1982.

The second half obviously carries a considerable appeal for business analysts. Now, for the third year in a row, as they ponder the business outlook, they foresee operations gathering strength during the latter part of the year. Unfortunately, neither in 1981 nor this year did the second-half upturn actually materialize. And as analysts look across the valley of recession, they are finding the dimensions of upward slope on the other side wrapped in mists of uncertainty.

Production of chemicals and synthetic materials in the U.S. has been on a protracted toboggan ride for most of the past two years. Now it is at a level 14% lower than it was at the end of last winter and 25% below its prerecession peak at the start of 1981. The slump has not been quite so severe as during the 1974–75 recession, when output of chemicals and synthetics collapsed 28% in just six months. But it has been much more protracted. For 1982 as a whole, output will average about 15% less than the year before.

The recession, too, has engulfed almost the entire diverse chemical industry. For example, production of inorganic chemicals is down about 25% from two years ago, and organic chemicals about 30%. Plastics output is off about 15% and synthetic fibers more than 25%. Output of agricultural chemicals is 15% lower than it was at the start of last year. The only sector of the overall chemicals and allied products industry to show any growth during the past two years is pharmaceuticals, now, as usual, relatively recession resistant; production of pharmaceuticals is running about 5% above what it was in early 1981.

The slump has had a severe impact on chemical companies' operations. Plants are running far below capacity, for one thing. A C&EN survey last fall shows that for 32 basic chemicals, operating rates were just a little more than 60% of nameplate capacity, down from nearly 75% of capacity in early 1981 and about 80% of capacity during 1979. Little wonder, then, that the industry is cutting back on capital spending about 10% this year from 1981's outlays and probably will make cuts of a similar degree in next year's capital budgets.

Employment also is lower, by more than 50,000 workers since mid-1981 for the industry as a whole, a decline of about 5%.

The real crunch, however, shows up in companies' income statements. By and large, they are not awash with red ink, as is the case in such other industries as automobiles, steel, nonferrous metals, farm equipment, and machinery—although Celanese reported a loss in the third quarter largely as a result of the effect of devaluation of the Mexican peso on its Mexican affiliate. But for producers of industrial chemicals, profits were down about 35% during the first nine months of 1982 from the like period a year earlier. And for the year as a whole, they are likely to trail 1981's peak about 35 to 40%. And as a result, profit margins will have dwindled to a mere 4% of sales this year, compared to nearly 6% in 1981—and less than half of what they were before the 1975–76 recession.

Again, the only bright spot this year is among drug manufacturers. Through the first nine months of 1981, their earnings were about 20% higher than a year earlier, and they probably will end the year with at least a 15% gain. Their biggest problem has been strength of the U.S. dollar abroad and the resulting losses in translating results from their big foreign operations to U.S. earnings. However, pharmaceutical companies that also have an extensive stake in chemicals, like Upjohn and Eli Lilly, have been hurt by the decline in the overall chemical business.

Even as the recession lingers on, economists have turned cautiously optimistic about business prospects for next year. Already, several early signs of recovery are evident. The government's series of leading indicators has been edging higher for most of the past nine months. Interest rates, although still high, have been declining. Inflation has slowed to an annual rate of about 4% in recent months. Consumer confidence, at least, by some measures, has turned higher, after having plunged late last year and early this year. New housing starts have made a modest rebound from their deeply depressed level of about a year ago, and sales of new cars last month were relatively brisk. The surge in stock prices, meanwhile, suggests that Wall Street sees better days ahead by U.S. business.

The current consensus of economists is pretty well summed up by the Conference Board's forum of 13 economic analysts, who early this month confidently forecast that "a long-awaited U.S. economic recovery will finally arrive in 1983." The forum noted, however, that "growth will not be broad based and will fall far short of rates registered after previous recessions."

The Conference Board group

projects real gross national product to grow at only a 2.7% rate in 1983, which is less than normal for the first year of a business recovery. The rate of inflation will drop to about 5% next year, it adds, down from 6% this year. But unemployment will average close to 10% of the U.S. labor force, down only slightly from the current level of about 11%.

Charles B. Reeder, chief economist for Du Pont, generally agrees with this forecast. He sees recovery next year generated by lower interest rates and a rise in consumer purchasing power, with real disposable personal income increasing nearly twice as fast as this year. With inventories cut significantly, output will have to rise faster than demand, and Reeder looks for turnaround in production no later than next month.

On the other hand, he adds, growth will be undercut by a decline in capital spending through most of 1983. U.S. exports also will be hurt by a rise in the value of the dollar, so that the U.S. trade deficit will soar.

All in all, Reeder looks for relatively small increases in real gross national product of 2% and in industrial production of 4 to 5% in 1983. But he adds that with inflation and interest rates declining, "the recovery should be easily sustainable beyond 1983."

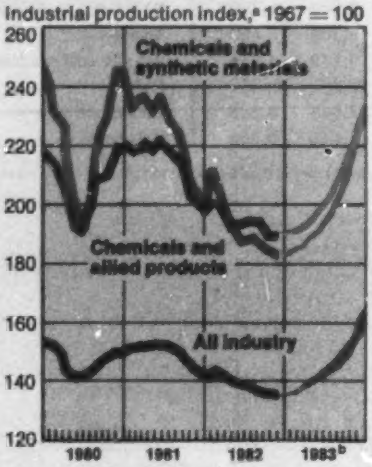
Union Carbide chief economist James F. Smith likewise expects consumer spending to lead the way to a recovery which, he says, "is finally taking hold in December." Smith thinks that gross national product (in constant dollars) will rise 3.3% in 1983, which he notes is only about half the growth usual in the first year of a recovery. But growth should be sustainable for at least three years, he adds, and "in an economy that has not moved in the same direction for longer than 270 days since June 1978, that will indeed be good news."

Certainly, recovery for the chemical industry hinges to a considerable degree on increased consumer outlays for such items as housing, cars, apparel, and appliances. Demand for homes and cars, in particular, is sensitive to interest rates and thus is expected to revive as the cost of borrowing declines.

The market for housing already is showing renewed life as basic mortgage rates fall slowly but steadily from the 16.9% rate of last July to an average of about 13.6% now, the lowest they have been since October 1980. Construction of new homes hit bottom in October 1981, when housing starts were at an annual rate (seasonally adjusted) of only 854,000. Since then, they have been moving upward shakily but gradually to a level of 1.12 million units last October, the most since May 1981. For 1982 as a whole, housing starts will total barely more than 1 million, the lowest number since the Commerce Department began collecting such data in 1959 and down 40% from just three years ago. Economists now are pegging next year's starts at 1.35 million to 1.5 million, a strong year-to-year gain but still well below the average annual rate of 1.8 million that prevailed during the 1970s.

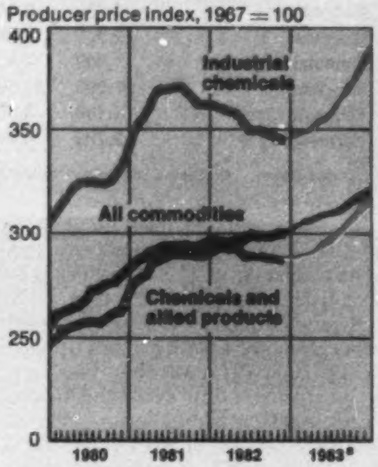
Economists also are hopeful that the automobile industry will be somewhat healthier in 1983. This year's output probably will be no more than 5.1 million cars, 18% lower than 1981's depressed level. Sales for the year are likely to be a mere 8 million units, 500,000 fewer than in 1981, with about all of the loss falling on U.S.-made autos. That means that domestic car sales, at 5.7 million units, will be at the lowest level in more than two decades. Next year, auto industry analysts are certain, will bring more robust sales as financing becomes less burdensome.

Next year will see a modest rebound in output...



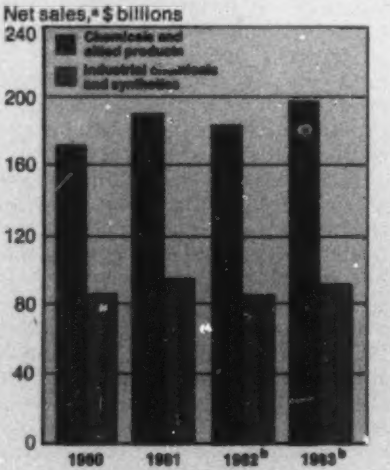
a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

...and some recovery in chemical selling prices...



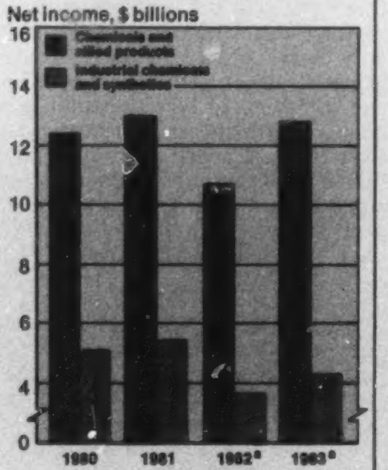
a C&EN estimates.
Source: Bureau of Labor Statistics

...which will help to revive sales volume...



a Excludes sales of foreign subsidiaries. b C&EN estimates. **Source:** Federal Trade Commission

...but won't restore profits to their previous peak



a C&EN estimates.
Source: Federal Trade Commission

Output of chemicals will make a moderate comeback next year after 1982's big slump

	1983	1982	1981	1980
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	16,500	15,600	19,038	19,653
Chlorine gas	8,800	8,250	10,559	11,421
Hydrochloric acid	2,600	2,400	2,443	2,895
Nitric acid	7,800	7,400	9,039	9,232
Oxygen, billions of cu ft	400	370	431	431
Phosphoric acid	9,000	8,400	9,914	10,938
Sodium hydroxide	9,700	9,100	10,649	11,625
Sulfuric acid	33,500	31,900	40,675	44,272
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	2,800	2,650	2,706	2,977
Acetone	1,900	1,750	2,167	2,076
Acrylonitrile	2,100	2,000	2,006	1,830
Benzene, millions of gal	1,250	1,100	1,348	1,585
Butadiene	2,500	2,000	3,046	2,799
Cumene	2,900	2,650	3,306	3,459
Cyclohexane	1,500	1,300	1,749	1,964
Ethylene	27,000	24,500	28,867	28,667
Ethylene glycol	4,150	3,850	4,055	4,386
Formaldehyde	5,200	4,750	5,855	5,555
Methanol	7,600	7,100	8,408	7,153
Phenol	2,300	2,100	2,551	2,568
Phthalic anhydride	800	725	811	818
Propylene	13,600	12,400	14,016	13,657
Styrene	6,400	5,900	6,612	6,856
o-Xylene	950	875	947	995
p-Xylene	3,300	3,000	3,696	4,238
PLASTICS				
Millions of lb				
Polyethylene, high density	5,100	4,700	4,695	4,405
Polyethylene, low density	7,800	7,250	7,693	7,291
Polypropylene	3,700	3,350	3,955	3,648
Polystyrene	3,500	3,250	3,621	3,521
Polyvinyl chloride	5,700	5,300	5,707	5,470
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	690	625	591	779
Nylon	2,100	1,900	2,332	2,358
Olefin and vinyon	800	720	785	748
Polyester	3,350	3,050	4,176	3,989

Sources: Bureau of the Census, International Trade Commission, Society of the Plastics Industry, Textile Economics Bureau, C&EN **estimates** (for 1982 and 1983)

But the recovery, some suspect, will only bring sales of U.S.-made cars to just a little above 1981's total.

Officials in the synthetic fibers industry, too, are betting on an upturn during 1983, although they fear that textile imports will continue to cut into domestic production as long as the dollar remains high valued. As a result, they are forecasting another troublesome year, one in which output may pull itself back only to 1981's level.

The farm market has been another sore spot for chemical producers. Farm income has been depressed for three years in a row in the wake of surplus crop production and markedly lower prices. Farmers, consequently, have neither the means nor the incentive to increase their purchases of fertilizers and pesticides. Pesticides, in particular, had been relatively immune to previous recessions in agriculture. Meanwhile, exports of both fertilizers and pesticides have slowed as the dollar has strengthened. It seems still too early to judge whether next year will bring any improvement.

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If a muted business recovery is about to get under way, next year will be a somewhat happier one for the U.S. chemical industry. But at the moment, at least, no one in the industry is expecting the rapid rebound that is typical of chemicals in past periods of recovery.

C&EN estimates that by the end of next year production of chemicals and synthetic materials will be about 25 to 30% higher than it is now. But that will put it back only to the level where it was 12 months ago, or perhaps a little bit below. In other words, output will have gone through four long years of relatively little or no growth. And for 1983 as a whole, production will be only 3 to 5% ahead of this year's unsatisfactory rate.

Increased demand and higher operating rates, however, should bring the industry some much needed relief from the depressed selling prices that have plagued it since early this year, if not before. Prices of industrial chemicals, on the average, are about 5% lower than a year ago, according to Bureau of Labor statistics. Next year, they can be expected to start rising again, although it may well be not until late next year that they recover to the peak level reached during the summer of 1981. For the year as a whole, prices of industrial chemicals are likely to average 2 to 3% higher than this year, when they were down nearly 3% from 1981.

That means that sales also will be higher for the basic chemical industry, after having dipped an unprecedented 10% this year. C&EN estimates that the dollar volume of sales can be expected to increase 5 to 10%, which would still keep it slightly beneath 1981's record high.

Profits should be much improved, as well. Wall Street analysts are figuring on a gain of about 30% in earnings for the leading producers of industrial chemicals in 1983. But even so, earnings will be well below what they were in 1981—or, for that matter, in either of the two preceding years as well.

For the entire chemicals and allied products industry, next years's results likewise will have a bit more luster. Continued health for pharmaceutical makers, whose earnings are likely to be up 15 to 20%, will get much of the credit, but so will a smart comeback for many producers of specialty chemicals, who are having a rare relatively poor year in 1982.

Sales for the overall industry are likely to rise 8 to 10%; this year they will be down about 3 to 5%. And profits probably will rise 20 to 25%, after a drop of 15 to 20% in 1982. That means that profits probably will be about at the same level as last year, which was their highest ever. □

Worldwide recession slams the brakes on foreign trade in chemicals

FOREIGN TRADE

Stagnant economies abroad and strong dollar stymie growth in U.S. chemical exports and squeeze chemical trade surplus

Earl V. Anderson, C&EN New York

World trade has grown so rapidly for so long that it has just about come to be taken for granted that growth would continue. That has proved to be wishful thinking. Even trade is not immune to the recession that has spread virtually throughout the world.

After chalking up an unblemished record of growth since 1958, the value of world trade (measured as exports) dipped 1.6% last year to $1.96 trillion. It is virtually certain to drop another 4 to 5% this year.

That means that world exports will have to wait awhile before they can boast of being a $2 trillion economy in their own right. They topped out at $1.99 billion in 1980.

What makes this pill of realism so hard to swallow is the recent history of world trade growth. In the three-year period from 1977 to 1980, world exports grew an average 20% per year. Admittedly, much of that growth represents the international flow of oil at inflated prices. But manufactures and agricultural products contributed their share.

Why the sudden turnaround? Obviously, economies throughout the world are in trouble. But there is no single or simple explanation for these economic problems. Many interrelated factors are involved; they are synergistic.

In industrialized and developing nations alike, stagnant economies result in a lower need to import. And there can be no exports without imports.

In many nations, particularly developing countries, current account balances are deteriorating. Debt service charges are mounting. Mexico is the prime example, but it is only one example. As a result, import quotas, special import fees, and a variety of other import restrictions are cropping up throughout the world. Many free traders in good times become protectionists in bad times.

This shifting is what lay behind the ministerial-level meeting of GATT (General Agreement on Tariffs & Trade) in Geneva last month. To some, results of the meeting were a disappointment. The ministers could not agree to remove some of the trade barriers that have arisen during the recession. But they did at least agree that their countries should avoid erecting new ones. Given the pessimism that surrounded the meeting, perhaps that was the best that could be expected.

In such an economically and politically sensitive climate, chemical exports could hardly thrive. And they haven't.

Chemical exports had been one of the brightest stars on the world trade horizon, rising from $61 billion in 1975 to more than $147 billion in 1980. That's a resounding 19.5% average annual growth rate.

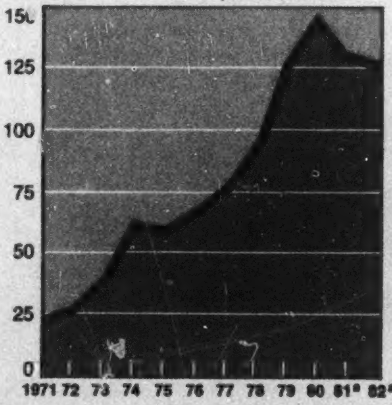
However, sagging import demand took its toll last year. World chemical exports tailed off 11% to $131 billion. With no improvement in the economic scene this year, they will drop again—to an estimated $126 billion.

Aided to a large degree by its feedstock advantage, the U.S. chemical industry managed to escape last year's axe. U.S. chemical exports edged up a slim 2% to $21.2 billion.

This year, however, the U.S.

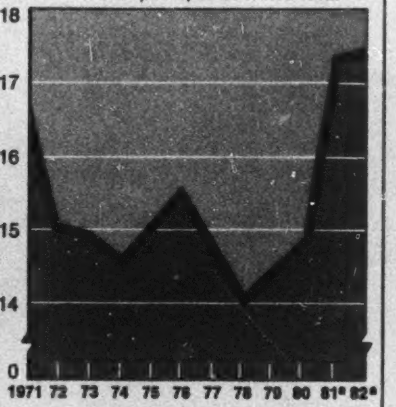
World trade in chemicals falters again this year . . .

Total world chemical exports, $ billions



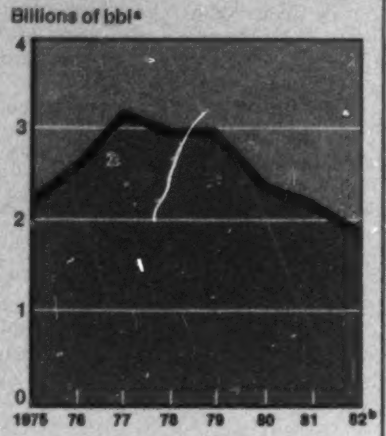
. . . but U.S. share is the highest in a decade

U.S. chemical exports, % of world total[b]

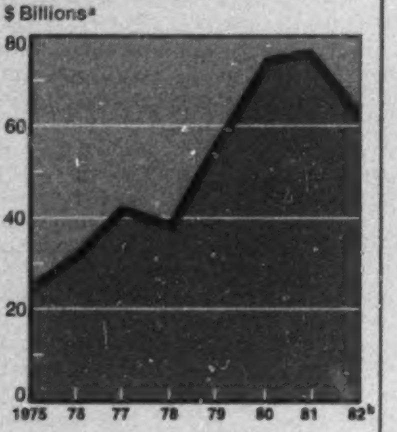


a C&EN estimates. b Defined as: U.S. chemical exports as per cent of world chemical exports less U.S. chemical imports. **Sources:** United Nations, Bureau of the Census

Volume of U.S. oil imports continues to decline . . .

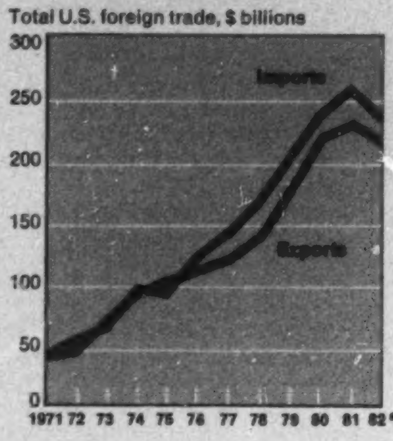


. . . as, for a change, so does their value

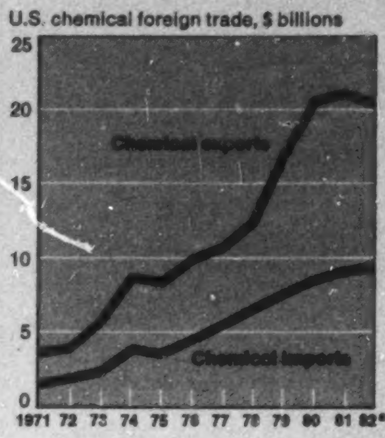


a All petroleum products. b C&EN estimate.
Source: Bureau of the Census

U.S. exports and imports are down this year . . .



. . . and the chemical trade balance narrows a bit



a C&EN estimates. Source: Bureau of the Census

chemical industry won't be as fortunate. World economic conditions finally will catch up with U.S. exports of chemicals, which probably will end the year at $20.4 billion, 3.7% lower than last year.

The losses were spread widely throughout various segments of the chemical industry. The only gains were registered by medicinals, radioactive materials, and pesticides.

Organics and inorganics, two big-volume product groups, will be down 5% and 12%, respectively. One of the hardest hit groups, however, will be fertilizer exports, which are likely to drop a hefty 19% to $1.4 billion. Plastics and resins, the second largest chemical export category, will squeak by with only a slight 1% drop.

Despite their economic problems, some major markets are holding up surprisingly well for U.S. chemical exporters. Western Europe, by far the largest foreign outlet, will import nearly as much chemicals from the U.S. this year as it did last year.

And U.S. chemical shipments to Japan actually will increase about 2% to $2.4 billion, even though Japan's economy is struggling and chemical demand there is weak. However, Japan's chemical industry is one of the world's high-cost producers, and imports are taking an increasingly large share of the Japanese market.

Canada and Latin America are particularly disappointing markets for U.S. chemical exports this year. That should come as no surprise.

In Canada, the recession is worse than it is in the U.S. and recovery

Organic chemicals, fertilizers lead drop in U.S. chemical exports; imports show little change

$ Millions	U.S. chemical exports				U.S. chemical imports			
	1982[a]	1981	1980	1979	1982[a]	1981	1980	1979
Organic chemicals	$ 5,630	$ 5,929	$ 5,697	$ 5,055	$2983	$2974	$2539	$2159
Plastics and resins	3,774	3,809	3,884	3,241	756	780	646	626
Medicinals and pharmaceuticals	2,264	2,165	1,932	1,591	557	583	508	441
Inorganic chemicals	2,020	2,286	2,106	2,712	1510	1573	1323	1106
Fertilizers, manufactured	1,408	1,735	2,265	1,404	991	1181	1104	976
Radioactive materials	1,142	988	833	937	1047	786	989	953
Pesticides and disinfectants	653	544	553	516	302	283	263	190
Flavors, perfumes, cosmetics, and toiletries	510	535	479	399	284	289	301	263
Pigments, paints, and varnishes	326	349	304	273	104	102	89	76
Cleaning and polishing materials	326	396	327	290	76	74	72	73
Dyeing, coloring, and tanning materials	163	175	186	177	208	226	194	185
Explosives and pyrotechnics	82	90	87	62	66	61	59	58
Miscellaneous	2,102	2,187	2,087	1,649	586	534	496	379
TOTAL	$20,400	$21,187	$20,740	$17,306	$9450	$9446	$8583	$7485

a C&EN estimates. Source: Bureau of the Census

Exports to American customers particularly hard hit this year

$ Millions	1982[a]	1981
U.S. CHEMICAL EXPORTS		
Canada	$ 2,244	$ 2,478
Latin America	3,876	4,469
Western Europe	6,242	6,251
Eastern Europe	306	347
Japan	2,407	2,349
Communist Asia	490	405
Middle East	551	517
Rest of Asia	2,693	2,598
Australasia	694	778
Africa	530	642
Other	367	353
TOTAL	$20,400	$21,187
U.S. CHEMICAL IMPORTS		
Canada	$2,504	$2,916
Latin America	605	669
Western Europe	4,167	3,917
Eastern Europe	142	131
Japan	898	956
Communist Asia	151	126
Middle East	113	110
Rest of Asia	217	197
Australasia	284	186
Africa	227	117
Other	142	121
TOTAL	$9,450	$9,445

a C&EN estimate. Source: Bureau of the Census

there will be slower. Meanwhile, Canada's chemical industry, gearing up to supply not only its own market but world markets as well, is running at unprofitably low operating rates. As a result, Canada will spend 9% less on U.S. chemicals ($2.2 billion) this year than it did last year.

In some of the major Latin American countries (Mexico, Brazil, Argentina, and Venezuela), economic conditions range from stagnant to disintegrating. Mexico and Brazil shoulder the world's largest foreign debt burdens. They and other Latin American countries are slapping tight controls on imports. This hurts U.S. chemical exporters because Latin America had been a $4 billion outlet for their products. This year, that market will shrink 13%.

As long as much of the world is floundering in an economic quagmire, there is little hope that U.S. chemical exports can improve significantly. And, as feedstock costs in the U.S. rise gradually to world levels, any improvement will become increasingly more difficult to realize.

But there is another handicap under which U.S. chemical exporters—indeed, all U.S. exporters—are operating. That is the U.S. dollar. The dollar has regained its old title as the world's strongest currency.

That, however, is a mixed blessing. Psychologically, Americans at home get a lift from it; Americans touring abroad find their dollars stretching further. To some extent, a strong dollar has helped in the battle against inflation in the U.S. But it also has cost U.S. exporters a competitive edge. A strong dollar makes exports more expensive to sell on world markets. And, by making imports less expensive, it enables them to penetrate the U.S. market more easily.

The Federal Reserve Bank of New York estimates that the appreciation of the dollar through this summer can be expected to increase the U.S. merchandise trade deficit by as much as $45 billion by the end of 1983. Export sales, the bank figures, will be roughly $35 billion lower than they would have been with a weaker dollar, but imports will be $10 billion higher. These estimates may be inexact. But they show clearly that currency exchange rates can take their place alongside economic conditions and trade policy as a major determinant in U.S. chemical trade.

With the U.S. economy in something less than great shape, it no doubt was the strong dollar that enabled foreign chemical companies to increase their shipments to the U.S. last year and to keep them at about the same level this year.

Although U.S. chemical exports grew only 2% in 1981, imports jumped 10% to $9.4 billion. As a result, the heralded chemical trade surplus slipped from $12.1 billion to $11.7 billion.

This year, while U.S. chemical exports are falling, imports are inching upward to $9.5 billion. Although that's a negligible advance, it still represents quite an achievement in this year's economic climate. It also means that the U.S. chemical trade surplus will dip to about $11 billion.

Although no one is expecting miracles next year by any stretch of the imagination, economic conditions probably will improve in many countries. U.S. chemical exports, then, probably will at least remain at 1982 levels and may even move upward slightly. With even a modest pickup in U.S. business activity, imports likely will increase again.

But factors other than economics influence trade flows. Much depends, for instance, on how successful world leaders are in curbing protectionism. France already has devised new rules to brake imports and stimulate exports. The U.K. is considering import controls, and Canada may toughen its import regulations. □

U.S. foreign trade declines for most product categories

$ Billions	1982[a]	1981
U.S. EXPORTS		
Chemicals	$ 20.4	$ 21.2
Machinery and transportation equipment	90.5	95.7
Other manufactured goods	33.9	37.3
Food and live animals	25.3	30.3
Beverages and tobacco	2.7	2.9
Mineral fuels, lubricants, and related materials	13.0	10.3
Crude materials (inedible) other than fuels	19.8	21.0
Animal and vegetable oils and fats	1.6	1.7
Miscellaneous products	6.7	8.4
TOTAL[b]	$216.5	$233.7

$ Billions	1982[a]	1981
U.S. IMPORTS		
Chemicals	$ 9.5	$ 9.4
Machinery and transportation equipment	75.0	69.7
Other manufactured goods	62.3	63.4
Food and live animals	14.1	15.2
Beverages and tobacco	3.2	3.1
Mineral fuels, lubricants, and related materials	65.5	81.4
Crude materials (inedible) other than fuels	8.7	11.0
Animal and vegetable oils and fats	0.3	0.5
Miscellaneous products	7.4	7.3
TOTAL	$246.0	$261.0

a C&EN estimates. b Includes re-exported imports (not included in individual product categories). Source: Bureau of the Census

Reduced supply may be only way to restore health to an ailing chemical industry

WESTERN EUROPE

Many chemical executives see plant shutdowns rather than growth in demand as best cure for present excess capacity

Dermot A. O'Sullivan, C&EN London

"1983 and the period beyond will confirm that the chemical industry in Europe isn't going to be as big as we used to think," declares David R. Clair, president of Essochem Europe. "Companies will have to implement aggressive cost-cutting and capacity reduction programs consistent with a lower-growth scenario."

Clair's admonition is in line with the ideas of other leading figures in the western European chemical industry. They articulated their thoughts more loudly and more clearly as this year progressed. For example, Jan H. Choufoer, managing director for chemicals at Royal Dutch/Shell, speaking at the Society of the Chemical Industry's meeting in Brussels in October, said, "There must be action taken to staunch the $200 million-per-month estimated level of losses. The process will be hard, as it will involve major reductions in capacity. The resultant industry will be smaller, of course. But the basic objective must be to ensure that European producers, who must continue to meet the major part of European demand, can thrive in the future."

In a similar vein, Aarnout A. Loudon, president of Akzo, the chemicals and fibers giant headquartered in Arnhem, the Netherlands, told the European Petrochemical Association's meeting in Venice this fall, "We are faced all over Europe with overcapacities and disastrously fierce competition. This is presenting a serious threat to the continued existence of the chemical industry."

Noting that a gap of as much as 40% now exists between western European production capability for most commodity chemicals and actual output, Loudon makes the point that "without clearcut effective action, there is no prospect of recovering a proper balance between supply and demand. Growth of only a few percentage points a year is so small that without such action, no balance can be attained before 1990."

Correcting overcapacities means that companies need to put their houses in order. But it takes courage and self-discipline to close production units permanently, especially if they are modern plants and basically efficient.

However, as Loudon points out, "The alternative is nothing less than a life-and-death battle between competitors, which can have the gravest consequences for the very survival of their companies and the preservation of jobs." Adds Essochem's Clair, "The industry must realize that restructuring occurs when each company, whether private or public, refuses to accept poor profitability and makes some tough decisions about its marginal operations. Hoping that the actions of others will save us will only prolong our individual agonies."

Certainly, western European chemical producers have been going through their "individual agonies" this year. For many, profits are down from 1981 levels. Among the three largest chemical firms in West Germany, for instance, pretax profit of BASF between January and September was off almost 40%, that of Bayer was down 20%, and Hoechst's pretax earnings declined nearly 24%.

Some firms have fared better, however. In the U.K., for instance, Fisons did an about-face during this year's first six months, moving into the black to the tune of $10.5 million against a $1.5 million loss in the like 1981 period. Ironically, however, its change of fortune stemmed from this year's sale of its fertilizer operations, a business the company was founded on, to Norway's Norsk Hydro. Others that have shown gains against year-earlier losses are Rhône-Poulenc in France, and Solvay and UCB in Belgium. Their improvements reflect corrective measures their managements have put into effect.

"There is growing awareness of the problems to be faced," remarks Paul Van der Grinten, vice president of planning and development at DSM in the Netherlands. "This will lead, in 1983, to a further decrease in the number of companies active in the petrochemicals sector, a prerequisite for capacity reductions."

So it is that top European chemical executives now are doing more than just thinking about what was all but unthinkable a short while back. Positive steps are under way to reorganize, retrench, and reshape their businesses.

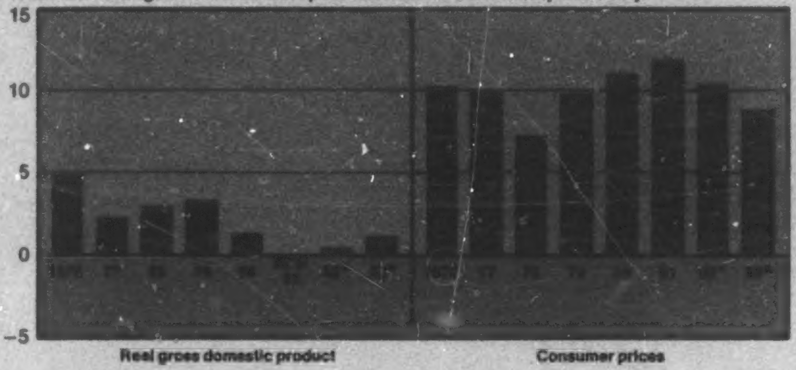
These steps include shutting production units and trimming staff. In Belgium and the Netherlands, the number of chemical industry workers has fallen 1% in the past 12 months. In West Germany, the drop is 2.5%, coupled with increased incidence of short-time work scheduling. In the U.K., the chemical labor force has been cut back 3.6% this year.

Even the ranks of white-collar workers and of corporate executives aren't escaping the drive to economize. One example is Royal Dutch/Shell's decision to shift its research emphasis. The 4000 or so workers at the company's four European research and development centers will be reduced about 20% during the coming three years.

Overhead expenses are coming under greater scrutiny, too. Monsanto U.K. made a quiet departure from its

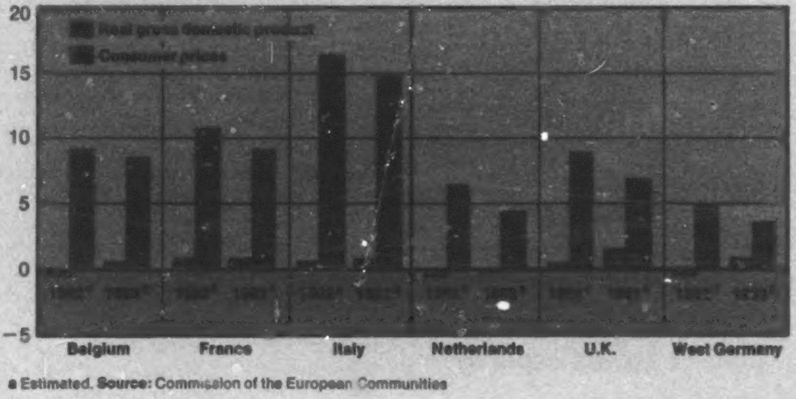
Economic recovery will be slow but inflation is easing . . .

% annual change for overall European Economic Community economy



. . . throughout major Western European countries

% annual change



a Estimated. Source: Commission of the European Communities

block-long London headquarters earlier this year to more modest premises nearby. The move, the company says, was the result of a decline of its work force. But termination of the lease saved Monsanto 23 cents a share in the third quarter, just short of 13% of total per-share earnings and more than enough to offset the cost of shutdown of its U.S. polyester staple business.

Nor has Monsanto been alone in switching office locations. Du Pont moved its U.K. central staff some 30 miles out of London last year. And just recently, directors of Imperial Chemical Industries made the startling announcement that they are preparing to leave their fortresslike London headquarters, occupied since the company was formed in 1926.

In ICI's case, the decision reflects a change in management policy and style that John Harvey-Jones has been pushing through, following his appointment as chairman in April. He has gone on record as saying that he seeks to introduce as many changes as the company can bear. Opting to leave IC House was "the most devastating decision for an ICI man to take," he admits. "But I believe that leadership has got to be by example, and has got to start at the top."

ICI's move to a new London headquarters isn't being made primarily on economic grounds, although it should result in substantial cost savings over the long term. Rather, the reason is strategic, stemming from the company's main board members having less involvement in day-to-day running of the business than they have had in the past. Instead, they will concentrate on such larger issues as portfolio management, strategic planning, and the overall direction of the company. Nonboard support staff will relocate at divisional headquarters elsewhere in the coming months. Precisely how many ICI people will remain in London isn't known yet, but the number will be considerably less than the current 1000 or so.

Dow Chemical also has been active in the recent retrenchment in European chemicals. Last month, the company announced its intention to pull out of its 49% interest in DINA, a Yugoslavian company formed in 1976 with Yugoslavia's Industrija Nafte (INA). The break becomes effective Jan. 15.

DINA is nearing completion of the first of a three-part petrochemical complex on Krk Island, just off the Yugoslavian coast. When it starts up next year, units there will have capacity for making 440 million lb of vinyl chloride, 330 million lb of ethylene dichloride, and 154 million lb of low-density polyethylene annually. Phase two involves a 440 million lb-a-year styrene plant. Phase three centers on a naphtha cracker, with an ethylene output capability of 880 million lb yearly, as well as units for making benzene (396 million lb), and high-density polyethylene (110 million lb).

There is some question as to whether phases two and three will materialize now that Dow has withdrawn from the venture, although Dow has told INA of "its willingness to cooperate on a new basis." Precisely what this implies isn't clear as yet.

When the project was launched, it was expected to cost $700 million and to be completed this year. Now, costs are expected to exceed even a $1.2 billion reassessment. The difficulty Yugoslavia is having in raising the necessary hard currency against the background of its weak financial situation, coupled with the global downturn in the petrochemicals business, prompted Dow's exit.

Besides, the move is in line with Dow management's desire to reduce its heavy debt burden and to lessen its involvement in the shaky commodity petrochemicals business. It wants to concentrate, instead, on specialties that provide better profit margins. Toward this end, Dow already has made changes in its partnerships in Asia and this month withdrew from its joint venture in Saudi Arabia.

Heavy losses in petrochemicals either must be written off by the shareholders, which is the government in many cases, or against profits from companies' other activities, such as pharmaceuticals, that are making money. "Now we are seeing these losses financed by increased borrowing," points out Jan J. Slechte, who heads Shell International Chemical's petrochemicals division. "As a result, the ratio of loan finance to shareholder equity, sometimes referred to as 'gearing,' has risen alarmingly.

"In periods of profitable growth, it may be a sound decision to increase a company's gearing to increase the asset base. But when cash is not being generated, seeking to cover the deficit by increased borrowing merely mortgages the balance sheet for continued operations.

"With the current lack of pricing discipline in the marketplace, companies are barely covering their variable costs and direct fixed costs. They are actually having to borrow to cover interest payments on loans, other fixed costs, and minor capital investment items. A better understanding of the extent to which this is happening would help management decide to raise prices or stop selling. Better financial discipline would help accelerate rationalization."

Certainly, a greater degree of rationalization is evident now than a year ago. Steps being taken include portfolio swaps and the creation of joint ventures. In February, for instance, Akzo Zout Chemie and Shell Nederland Chemie formed a joint venture, Rotterdamse Vinylunie, or Rovin for short, to bolster their respective positions in vinyl chloride and polyvinyl chloride. In the past, Akzo has been making vinyl chloride near Rotterdam using its own chlorine and ethylene supplied by neighboring Shell. The monomer then was sold to Shell for conversion to PVC. Now both companies participate in the entire operation.

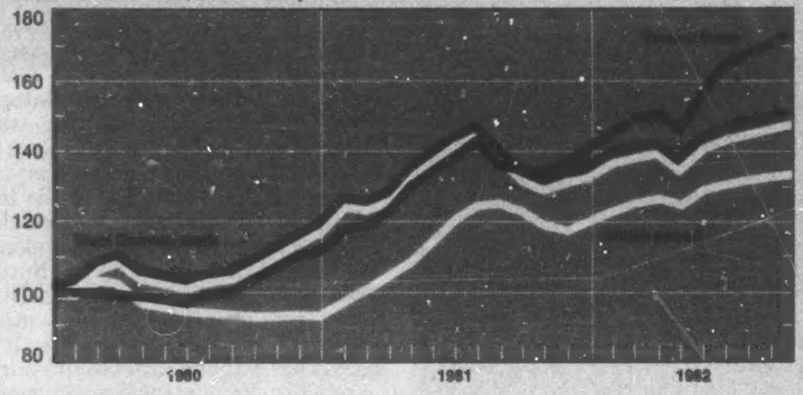
The arrangement hasn't fundamentally changed the existing infrastructure, and PVC capacity remains at 396 million lb per year, Slechte admits. "But through this combination, there is a stronger operational unit, which increases leverage over a number of competitors," he points out.

ICI also has strengthened its longstanding PVC position in Europe through acquisition of the PVC operations of Lonza, the chemicals arm of Switzerland's Alusuisse. The purchase, which will be phased over three years beginning Jan. 1, will include polymer units at Sins, Switzerland, and Waldshut, West Germany, that have a combined annual capacity of 176 million lb. In itself, this isn't particularly large. But the move lessens competition in the market and adds to ICI's existing 253 million lb-a-year PVC capability at Wilhelmshaven, West Germany.

In a more daring PVC-related step, BP Chemicals and ICI entered into a product swap agreement in the U.K. this past summer. BP Chemicals transferred to ICI its new 198 million lb-a-year PVC plant at Barry, Wales. At the same time, it closed down a 132 million-lb unit there, along with associated chlorine, ethylene dichloride, and vinyl chloride operations. For its part, ICI will transfer its 154 million-lb low-density polyethylene plant at Wilton, England, to BP Chemicals, along with its technology and U.K. customer order book; close two older units; and withdraw from the U.K. low-density polyethylene business. Through this maneuvering, ICI eventually will emerge with a European PVC capacity of more than 1.25 billion lb, making it the second largest producer of the polymer in Europe after Belgium's Solvay.

European currencies weaken further against U.S. dollar

Relative value of U.S. dollar vs. French franc, West German mark, and British pound[a]



[a] January 1980 = 100.

A more complex and far-reaching intercompany realignment is under way in Italy. There, three corporate entities are directly involved—Ente Nazionale Idrocarburi (ENI), the Italian state-owned hydrocarbons and chemicals concern; Enoxy Chemical, jointly owned by ENI and Occidental Petroleum; and Montedison, Italy's largest private chemical company—with the Italian government standing in the wings.

Enoxy Chemical's growth has been rapid during its 12-month existence. The company has assumed ownership of the U.K.'s former International Synthetic Rubber Co. But it is in Italy where most of its acquisitions have taken place, with encouragement from the Italian government, which has been seeking ways to improve the country's ailing chemical fortunes. Enoxy now has 56 plants there, making a wide range of products including lower olefins, high-density and low-density polyethylene, polypropylene, polystyrene, chlorine, vinyl chloride, PVC, and a range of synthetic rubbers and latexes.

Last month, a new 1.32 billion lb-per-year (of ethylene) cracker, Western Europe's largest, owned jointly by Enoxy and Montedison, came into production at Priolo, Sicily. Enoxy Chemical is to take over sole ownership of the cracker, together with complete segments of Montedison's petrochemical activities.

In the new lineup, as now envisioned, Enoxy will be the single Italian producer of acrylonitrile-butadiene-styrene resins, high- and low-density polyethylene, PVC, and synthetic rubber. Enoxy's polypropylene and polystyrene activities, meanwhile, will pass to Montedison.

France is where the most widespread national realignment of the chemical industry is taking place. The development is a direct outgrowth of the nationalization of leading companies by France's socialist government under President François Mitterand, voted into office last year.

One result is that Produits Chimique-Ugine-Kuhlmann (PCUK), the erstwhile chemicals arm of Péchiney-Ugine-Kuhlmann, ceases to exist. Production facilities for an extensive range of chemicals both in France and elsewhere are being shared between CdF Chimie, Entreprise Miniere et Chimique, Rhône-Poulenc, and Société Nationale Elf-Aquitaine, all state-owned companies. Research and development activities will be absorbed by Elf. ICI, meanwhile, is taking over PCUK's dyes and pigments division. This mammoth French undertaking will take months to complete. It will entail numerous plant closures and the problem of coping with the 12,500 or so workers who will be affected.

France's fertilizer industry also is going through a shakeup. Details have yet to be finalized. But it is likely that about 12 of the country's 34 fertilizer

West European petrochemical capacity is now far above demand

Billion of lb	1981	1985	% annual change
Ethylene			
Effective capacity	34.8	33.7	−0.8%
Consumption	22.6	26.0	3.6
Propylene			
Effective capacity	19.2	18.9	−0.4
Consumption	12.6	14.5	3.6
Benzene			
Effective capacity	15.1	15.9	1.2
Consumption	9.3	10.6	3.2
Polyethylene, high density			
Effective capacity	4.4	4.7	1.5
Consumption	3.1	3.6	4.4
Polyethylene, low density			
Effective capacity	11.0	10.5	−1.2
Consumption	7.4	7.5	0.6
Polypropylene			
Effective capacity	4.8	4.9	0.6
Consumption	3.0	4.0	7.8
Polystyrene			
Effective capacity	5.8	5.6	−0.6
Consumption	3.4	3.8	2.5
Polyvinyl chloride			
Effective capacity	11.1	11.3	0.4
Consumption	7.6	8.4	2.5

Source: European Council of Chemical Manufacturers' Federations, ChemSystems

facilities will be shut to make this sector of the chemical industry more efficient and reverse its losses.

France's nationalization program has had an indirect effect on the European chemical industry as a whole. Jean Gandois resigned as head of Rhône-Poulenc because of disagreement with the government's policies within weeks of taking over the presidency of the European Council of Chemical Manufacturers' Federations (CEFIC). A trans-European scramble ensued to find a replacement for him at CEFIC. The post now has been filled by Mario Schimberni, Montedison's president.

Voicing CEFIC's viewpoint on how the present situation in Europe might be remedied, Schimberni states, "The industry itself must face the major structural problems that are troubling it. It must be capable of reaching an equilibrium between supply capability and market demand in a reasonable time."

A dialogue of sorts was begun with the commissioners of the European Communities when the leaders of eight companies visited them at their Brussels headquarters last July. Represented were ATO Chimie, BASF, DSM, Hoechst, ICI, Montedison, Royal Dutch/Shell, and Solvay. The meeting was to alert the commissioners to the problems that European makers of bulk thermoplastics are going through and to sound them out on their responsiveness to some form of industrywide regulatory mechanism. Nothing definite was decided, but the door remains open if future talks are deemed necessary.

Opinion is divided within the industry on the desirability of establishing a crisis cartel somewhat along the lines of that set up by the European man-made fibers producers. But apart from differences in basic attitudes toward such a measure, it's hardly likely that a cartel would work in practice. For one thing, many more companies are involved, some 20 per product. Moreover, a number of them are subsidiaries of U.S. concerns, and U.S. antitrust regulations would stand in the way of their participating in any collaborative dialogue between competitors.

On the synthetic fibers front, agreement has been reached between nine European Economic Community producers to trim overall capacity further. The plan was drawn up under the guidance of the Paris-based International Rayon & Synthetic Fibers Committee (CIRFS). It calls for a cutback of some 1.1 billion lb from the 6.4 billion lb total capacity of acrylic fiber, nylon, polyester filament and staple, and nylon carpet yarn. This follows an 880 million lb reduction in capacity instigated in 1978.

Output of synthetic fibers in Western Europe will be down from last year to 1.42 billion lb for acrylic, 1.25 billion lb for nylon, and 1.59 billion lb for polyester. What this means is that neither acrylic nor polyester fibers underwent any significant change in annual production between 1977 and 1982, whereas production of nylon fibers declined by an average 3.3% a year during the same period.

Du Pont now is out of commodity synthetic fibers production in Europe with the closure this year of its polyester filament yarn plant at Uentrop, West Germany. However, the company is firmly committed to continuing business in Europe. It still makes polyester staple and fiberfill and nylon 66 staple and carpet yarn, together with polyamide resins, at Uentrop. A major polyester elastomer operation in Luxembourg will be completed in 1984. Expansions to the fluorinated chemicals complex at Dordrecht, the Netherlands, will make it the largest anywhere, the company claims. Its Hypalon chlorosulfonated polyethylene facility at Maydown, Northern Ireland, will come on stream next year. All told, Du Pont is investing $300 million on these and other projects. This year also saw the launch of Du Pont's pharmaceuticals in Europe.

The malaise of Western Europe's chemical industry is a direct reflection of the weak economies not only of countries in Europe, but elsewhere. All areas of industrial activity are down, from automobile output to steel, and unemployment levels are high. Indeed, the EEC annual economic report this year makes for some grave reading. It points to the very real possibility of the European economy entering a long period of slow growth, or even depression.

"The recovery forecast last spring for the second half of 1982 has not materialized," it states. "The positive factors in the second half of 1981, which appeared to be pointing to an upswing, were reversed. The outcome for 1982 is approximate stagnation, with a rise in volume of output in the community of only 0.3%.

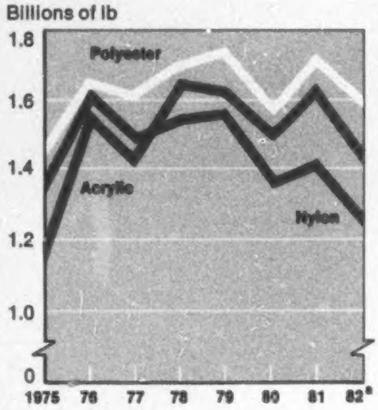
"The forecast suggests that the trend of output growth is likely to remain weak. World trade should recover somewhat in 1983, but it is unlikely that the foreign sector will make an important contribution to growth in the community. The European economy is seen as having a second downward phase in a double-dip recession. The beginnings of a recovery phase have clearly been extinguished."

As for labor, the number of unemployed in EEC now stands at about 11 million, 9.4% of the labor force. This is likely to rise during the second half of next year "to reach well over 12 million." Worst hit are Belgium, where unemployment now stands at about 14%, followed by Ireland and the U.K., with the unemployment rate exceeding 12% in both. Denmark, France, Italy, and the Netherlands aren't far behind.

On a somewhat brighter note, the report points out that "some limited progress is being made in the struggle against inflation. It is expected to fall faster in 1983 than was expected previously." The rise in consumer prices for the EEC as a whole this year averaged 10.5%, compared to last year's 12%. For 1983, the increase is expected to fall back further to around 9%.

Those countries with the dubious distinction of having the highest inflation levels are Greece (23%), Ireland (19%), and Italy (17%). The U.K.

Fiber production stumbles again this year



a Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

successfully moved into single figures to just under 9%. The rate of inflation in the U.K. is expected to decline to 7% next year if the government can maintain its deflationary policies.

Concern about job security tended to keep wage rises this year at a lower level than in the recent past. This is one positive factor sited by chemical companies that C&EN has polled. The French government, in fact, imposed a wage and price freeze for several months during the year. And salaried employees throughout West Germany's chemical industry will have to forego their customary end-of-year pay adjustment, now postponed until next summer. A hoped-for effect of this move is that worker unions will temper their demands at the forthcoming round of wage negotiations.

Another favorable factor that petrochemical companies point to is that the prices of hydrocarbon feedstocks—oil and naphtha—have remained steady throughout 1982. There's a catch here, however. Hydrocarbons are priced in U.S. dollars. And the dollar's continued strength against European currencies during the past three years has meant that the prices of oil and naphtha in terms of European money have risen noticeably.

This year alone, the dollar strengthened by more than 10% against the West German deutsche mark, by 11% against the British pound, and by almost 23% against the French franc. The franc's case admittedly wasn't helped by a 9% devaluation at midyear. The U.K.'s Department of Industry attributes last month's 2.1% increase in the price of fuel and raw materials to the October fall in the pound's value.

The parity of a country's currency, of course, is something of a two-sided coin. Although a strong dollar raises the local price of oil and related products in weak currency areas, it provides a stimulus to exports from those countries. It also lessens the competitive threat of imports arriving from dollar trading zones.

A strong dollar notwithstanding, there are instances of proven and alleged dumping of U.S. chemicals on western European markets. There now are 24 products, ranging from ammonia-based fertilizers to vinyl acetate, in various stages of investigation by the EC Commission, more than half of them arriving from the U.S. Most of the cases have arisen from complaints that CEFIC launched on behalf of local producers.

The most recent action involves U.S. natural soda ash. Last month, the commission set a provisional antidumping duty of upward to $22.40 a ton on the material, with the exception of that sold by Allied and FMC, who are making price adjustments. According to CEFIC's figures, imports of U.S. soda ash into EEC rose from 31 million lb in 1979 to nearly 106 million lb last year. They went up further to an estimated 217 million lb in this year's first nine months.

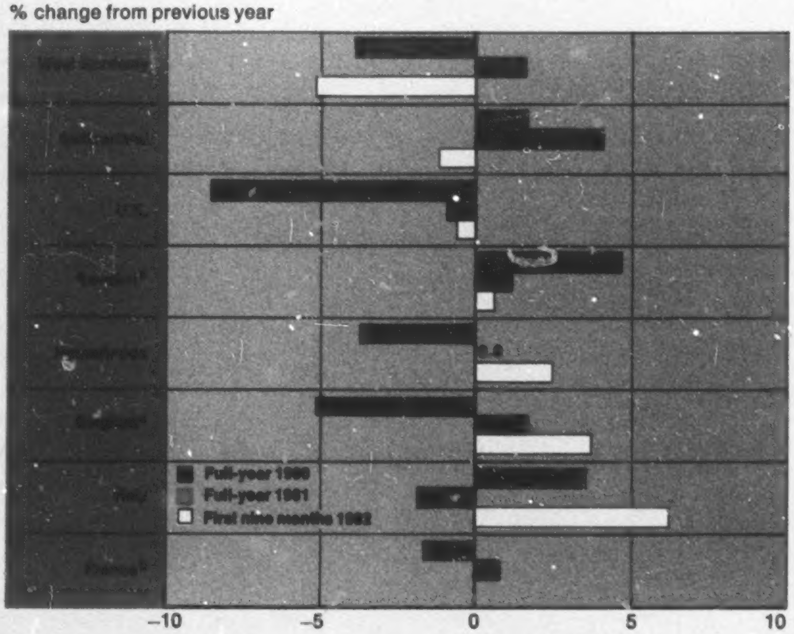
In all fairness, the U.S. isn't the sole target of dumping investigations. A provisional antidumping duty was put on Bulgarian soda ash last June. Indeed, nine of the 24 products considered as being dumped in the EEC originate in Eastern Europe.

With demand down and competition intense, there have been increasing hints in some government circles about the need to establish some protectionist measures. Chemical executives generally oppose any move in that direction.

"The rise of unemployment is becoming less and less acceptable politically, and import restrictions are looked at as a quick fix," admits Shell International Chemical's Slechte. "But they are a potential drug in the system, and there is a great danger of people becoming dependent on them.

"When industry is in the sort of difficulty that we have today, managers intuitively look to factors over which they haven't control, like imports from the East Bloc, the U.S., the Middle East, and Canada or the strength or weakness of the currency in which they are operating. All these obviously count. But they are an inadequate excuse for the industry at large to blame its ills on, the real ill being the degree of overcapacity that still exists." ◻

Chemical output down in West Germany, Switzerland, U.K.



a 1982 figure is for first six months only. b First-nine-months 1982 figure is not available.
Note: Data exclude synthetic fibers. **Source:** National chemical federations for each country

High costs and stiff competition plague petrochemical producers

Japanese imports of ethylene glycol in 1978 accounted for only 6% of domestic supply.

There's a seemingly insignificant statistic if there ever was one. It's insignificant, however, only until coupled with the fact that imported ethylene glycol soared to 27% of total domestic supply during the first half of this year. Then it helps spotlight all the problems that now are plaguing the Japanese petrochemical industry.

The industry, clearly, is having trouble competing with imports. Similar statistics for ethylene dichloride, vinyl chloride, low-density polyethylene, styrene, and a host of other large-volume petrochemicals, mostly ethylene derivatives, confirm this.

Imports of all chemicals are likely to be up almost 10% in 1982, a year in which domestic demand is nothing to brag about. At an estimated $7.1 billion, chemical imports will top chemical exports and give the country its first chemical trade deficit in well over a decade.

In addition to the troubles it has competing with imports at home, Japan's petrochemical industry is having even more trouble competing in export markets, particularly in its traditional and critical markets of Southeast Asia.

JAPAN

Excess capacity and loss of its competitive edge may force a restructuring on Japan's hard-pressed petrochemical industry

Earl V. Anderson, C&EN New York

In the past, about 20% of Japan's ethylene production was exported, mostly in the form of derivatives. Last year, exports consumed only 12% of Japan's ethylene production.

In part because of the worldwide economic slowdown, but also because its petrochemical industry simply is no longer competitive, Japan's chemical exports will decline 6.5% this year to about $6.4 billion. Although growth rates have been slowing recently, this will mark the first time that chemical exports have actually dropped since the recession years of 1975–76.

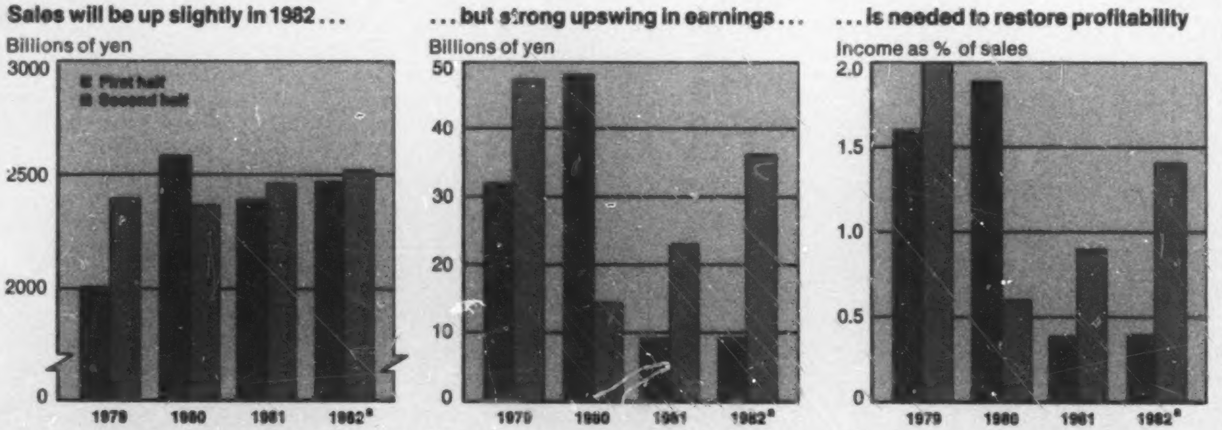
The reasons behind this decline are, by now, all too familiar. The industry's lifeblood is naphtha, which is either imported or produced domestically from imported crude oil. Either way, naphtha is expensive feedstock.

As a result, the basic petrochemical building blocks and their derivatives are much more expensive to produce in Japan than they are in areas that are close to natural gas-based feedstocks.

Many of Japan's petrochemical core units also are too old, too small, and too inefficient. And there are too many of them for the size of the market.

Competition is fierce among Japanese petrochemical companies. Their selling prices can't keep pace with rising raw material costs. Profitable companies are few and far between.

All of this adds up to what the Japanese call a "structurally depressed industry." And the Japanese



Petrochemical producers see some recovery in this year's second half

a Estimated. **Note:** Data for fiscal years ending March 31. Based on results of 10 leading Japanese petrochemical companies: Mitsubishi Chemical Industries, Sumitomo Chemical, Asahi Chemical Industry, Toray Industries, Mitsui Toatsu Chemicals, Teijin, Showa Denko, Mitsubishi Petrochemical, Dainippon Ink & Chemicals, and Sekisui Chemical. **Source:** Toyo Keizai Shinposha are attempting to do something to solve the problem in a typical Japanese fashion.

Earlier this year, Japan's Fair Trade Commission authorized the country's 12 ethylene producers to form an antirecession cartel. The first such cartel in 10 years, it will run for 5.5 months (from Oct. 16, 1982, through the end of March 1983.

The authorization limits ethylene output during that period to 1.56 million metric tons, down 3.6% from the corresponding period a year ago. Average ethylene plant operating rates will be restricted to 56% of capacity, compared to a precartel level of just over 60%.

To put this in perspective, ethylene production during this period will be at a 3.4 million metric ton annual rate. Output in Japan peaked in 1979 at 4.8 million metric tons and has been edging downward ever since. Last year, production was only 3.6 million metric tons and it was down 4% more during the first six months of this year.

In addition, a petrochemical industry committee of the Industrial Structure Council has urged the Ministry of International Trade & Industry to orchestrate a 35% reduction in ethylene capacity by 1985. Capacity now is rated at 6.2 million metric tons annually. The committee also is suggesting similar cuts in the capacity of many ethylene derivatives.

Its recommendation is based on an estimated 1985 production requirement of 3.7 million metric tons, not much more than last year's level. Supporting this recommendation is the virtual certainty that petrochemical exports will continue to decline and that exports will continue to rise.

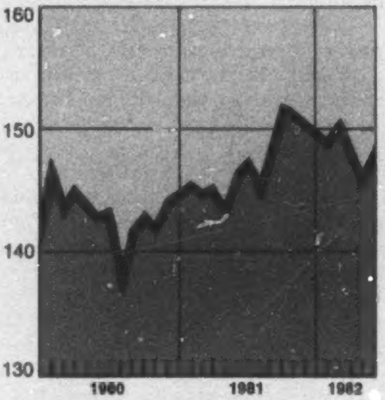
At the proposed production rate, petrochemical imports are expected to range between 200,000 and 900,000 metric tons in 1985 and between 900,000 and 1.5 million metric tons in 1990. All of these figures are on a net ethylene basis.

The planned capacity cut would establish 1985 ethylene capacity at 4.1 million metric tons. This implies a 90% operating rate for ethylene pro-

Chemical production remains below 1980 peak

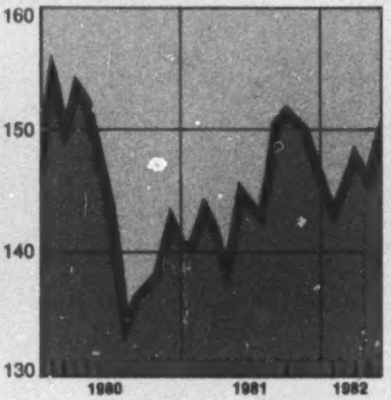
All manufacturing

Production index, 1975 = 100[a]



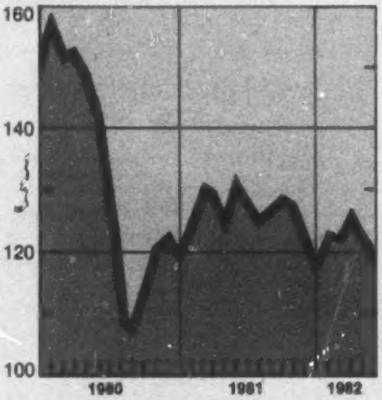
All chemicals

Production index, 1975 = 100[a]



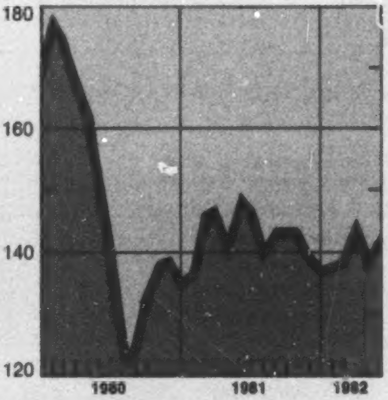
Petrochemicals

Production index, 1975 = 100[a]



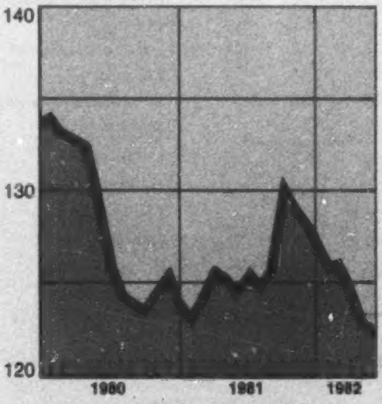
Plastics

Production index, 1975 = 100[a]



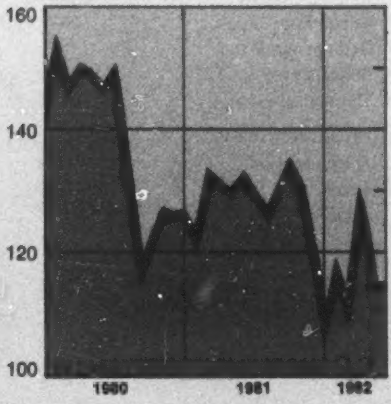
Synthetic fibers

Production index, 1975 = 100[a]



Synthetic rubber

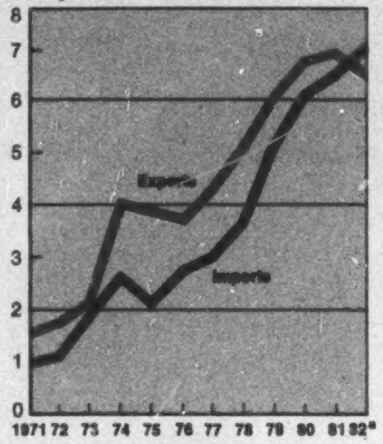
Production index, 1975 = 100[a]



[a] Seasonally adjusted. Source: Ministry of International Trade & Industry

Chemical trade balance slips from surplus to deficit

Foreign trade in chemicals, $ billions



a C&EN estimates. Source: Ministry of International Trade & Industry

ducers and a possible return to respectable profitability.

Meanwhile, plans already are under way to condense the 12 Japanese ethylene producers into four groups to produce and market ethylene and its derivatives. The Mitsubishi group is expected to include Mitsubishi Petrochemical, Mitsubishi Chemical, and Sin-Daikyowa. Mitsui Petrochemical, Nippon Petrochemicals, and Osaka Petrochemical Industries will make up the Mitsui group. Forming the Chiba group will be Sumitomo Chemical, Maruzen Petrochemical, Idemitsu Petrochemical, and Tonen Sekiyukagaku. The last group, as yet unnamed, will list Showa Denke and Sanyo Petrochemical as members.

In fact, throughout the entire Japanese chemical industry, antirecession cartels and joint selling arrangements are the order of the day. In some product areas, companies are joining together to import the very products that they produce.

The rationale is that joint purchasing power will guarantee more attractive import prices under long-term contracts. But it hasn't escaped these companies that they will maintain better control over the production-import mix than they would have if they allowed their customers to do their own importing.

Just how far Japan's chemical industry can or will go toward cartel-type rationalization is difficult to say. Japanese chemical companies are very competitive and are jealous of market share. They may not be able to stay in bed comfortably together. September's ethylene production, for example, shot needlessly up in anticipation of the cartel's arrival in October.

And the Fair Trade Commission, although it has approved many antirecession cartels, opposes the idea of government doing all that it can to save structurally depressed industries. It contends that, by artificially sustaining weak industries, the country is wasting economic muscle that could be used more effectively elsewhere. It also believes that the cartels invite criticism, if not retaliation, by Japan's foreign trade partners.

However, the commission will have to lock horns with the powerful Ministry of International Trade & Industry. And there's no doubt that the petrochemical industry needs some form of help.

One study concludes that the industry will have to push profits up from a negative 5% of sales to a positive 10% to maintain its health. "The natural approach," says the study, "would be rationalization . . . within a reasonable period of time." ◻

Volume is lower for most major chemical products this year

Thousands of metric tons unless otherwise indicated	1981	Six months 1982	Six months 1981	% change
INORGANIC CHEMICALS				
Ammonium chloride	584	245	302	−19%
Ammonium sulfate	1815	855	915	−7
Calcium carbide	495	267	267	0
Calcium superphosphate	483	284	254	12
Carbon black	557	255	280	−9
Chlorine, liquid	764	408	381	7
Hydrochloric acid	565	283	289	−2
Nitrogen[a]	5147	2633	2550	3
Oxygen[a]	6603	3331	3231	3
Sodium carbonate	1175	574	607	−5
Sodium hydroxide	2871	1410	1432	−2
Sodium silicate	692	323	357	−10
Sulfuric acid	6572	3246	3274	−1
Titanium dioxide	176	93	90	3
ORGANIC CHEMICALS				
Acetaldehyde	324	146	164	−11
Acetic acid	365	177	179	−1
Acetone	225	114	110	4
Acrylonitrile	477	241	235	3
Benzene	1899	899	949	−5
Butadiene	518	256	258	−1
Butanol	237	108	113	−4
Caprolactam	427	200	216	−7
Cyclohexane	475	213	226	−6
Dioctyl phthalate	223	106	112	−5
Ethylene	3647	1792	1869	−4
Ethylene dichloride	1650	744	875	−15
Ethylene glycol	411	181	182	−1
Ethylene oxide	478	228	220	4
Methanol	734	353	380	−7
Octanol	239	102	110	−7
Phenol	214	101	111	−9
Phthalic anhydride	254	132	124	6
Propylene	2538	1237	1230	1
Propylene glycol	171	91	81	12
Styrene	1095	515	538	−4
Terephthalic acid	635	317	307	3
Toluene	821	406	420	−3
Toluene isocyanate	64	29	27	7
Xylene	1262	596	579	3
Urea	1483	632	804	−21
PLASTICS				
Phenolic resins	294	140	144	−3
Polyethylene	1671	840	883	−5
Polypropylene	959	462	482	−4
Polystyrene	1183	582	566	3
Polyvinyl chloride	1129	560	598	−6
SYNTHETIC RUBBER	1010	455	506	−10

a Millions of cubic meters. Source: Ministry of International Trade & Industry

Chemical companies seek relief from the burden of feedstock costs

CANADA

Export sales are down this year as high cost of oil makes Canadian chemicals less competitive in world markets

Earl V. Anderson, C&EN New York

Until very recently, Canadian petrochemical executives were talking enthusiastically about a "window of opportunity." Today, however, they are talking about a "window of survival."

Blessed with ample supplies of oil and natural gas that would be maintained below world price levels by government decree, Canada's chemical companies launched a program of massive, world-scale plant building that would serve not only the domestic Canadian market, but the world market as well. By moving fast, Canada's petrochemical industry figured it could rush through its window of opportunity before potential competitors, such as Mexico and Saudi Arabia, could make an impact on the international marketplace.

At the time, the scenario made sense. But Canadian petrochemical producers didn't reckon with two developments that struck them simultaneously and now put that scenario in jeopardy.

Like the chemical industries in many other countries, Canadian producers have had to cope with a recession-weakened market, both at home and abroad. But unlike the industries in other countries, particularly the U.S., they have had to contend with a government energy pricing policy that pushed up the costs of feedstock at a time when such costs were dropping in other parts of the world.

The consequences are not surprising. Production is down. Plant operating rates are low. Profits, caught in a classic cost-price squeeze, have evaporated. Because of cash flow problems and budget restraints, companies are delaying some plant construction plans and canceling others. Meanwhile, the Canadian petrochemical industry is pressuring its government to lighten the feedstock cost burden.

This year's slump in production hit the Canadian chemical industry across the board. Basic petrochemicals, intermediates, plastics, industrial inorganic chemicals, and fertilizer all suffered.

Output of ethylene—cornerstone of the Canadian petrochemical industry—will be down about 27% this year, and consequently so will much of the industry's expansion plans. Alberta Gas Ethylene's unit at Red Deer, Alta., shut down in July. Oil-based producers in Sarnia, Ont., and Montreal, Que., extended scheduled downtimes because of weak demand. Operating rates in all areas are low.

On the aromatics side, benzene production will be 15% less than it was last year. Plastics haven't fared much better. Output of polyethylene, polyvinyl chloride, and polystyrene all are off about 10%.

Chlor-alkali producers are faring better than most. Chlorine output probably will be down only 2.5%, and caustic production will be 4% lower. But that's only because Canadian producers have a substantial market in the U.S. Sulfuric acid output, on the other hand, will decline about 20% this year.

Competitive natural gas costs have enabled Canadian ammonia producers to maintain fairly healthy markets. Production of ammonia probably will be off only about 3% this year, again because Canadian producers get a big share of their business from customers in the U.S.

Were it not for exports, in fact, the entire Canadian chemical industry would be in worse shape than it is. Exports are an important part of the chemical picture in Canada; they have more than quadrupled since 1975.

This year, however, even export sales are down—about 9% from last

Production plummets for just about all leading chemicals

Thousands of metric tons	1982[a]	1981	1980	1979	1978
Ammonia	2570	2654	2555	2405	2398
Ammonium nitrate	790	911	873	914	871
Ammonium phosphate	915	1355	1466	1336	1178
Benzene	480	566	604	492	555
Chlorine	1260	1292	1303	1031	941
Ethylene	960	1330	1184	1014	826
Hydrochloric acid, 100%	135	186	177	154	155
Phosphoric acid, 100% P_2O_5	535	744	808	748	554
Polyethylene	610	674	641	628	478
Polystyrene	135	123	110	124	99
Polyvinyl chloride	200	222	190	145	125
Sodium chlorate	250	254	245	224	199
Sodium hydroxide	1400	1458	1459	1138	1036
Sulfuric acid	3325	4117	4295	3666	3261
Urea	1220	1303	1274	1212	1217

a C&EN estimates. Source: Statistics Canada year's record $4.6 billion (Canadian) to $4.2 billion. However, Canadian chemical companies were able to maintain those export sales only by shaving their prices and sacrificing profits.

Weak Canadian markets also have forced chemical imports down this year. They are likely to end the year off about 4% at $3.7 billion as a result, enabling the industry to chalk up a $530 million surplus in chemical trade. It will be the fourth successive surplus in Canada's trade balance for chemicals, after years of deficits.

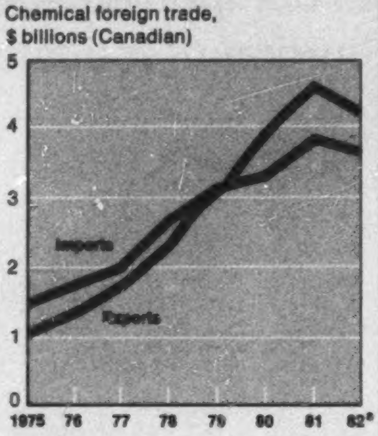
Weak foreign sales at little or no profit, even weaker domestic sales, and rapidly rising feedstock costs all are combining to splatter chemical companies' income statements with red ink.

For instance, the combined nine-month sales of five large Canadian chemical companies (C-I-L, Celanese Canada, DuPont Canada, Polysar, and Union Carbide Canada) fell 9% this year compared to the same period last year. More important, net income was down a whopping 28%.

With the exception of C-I-L, all these companies have been losing money on their operations this year. And even C-I-L's profits are down more than 60%.

The combined quarterly earnings of these companies have been less than those in the corresponding quarter of the preceding year for eight successive quarters now. But the big blow came in this year's third quarter. The combined loss hit a staggering $24.1 million in that three-month period alone.

Chemical trade declines but surplus continues



a C&EN estimates. Source: Statistics Canada

Late in the third quarter and early in the fourth quarter, there were a few scattered signs of an improvement in Canadian chemical production. But these improvements certainly do not indicate a general, across-the-board recovery.

Even if the forecasters are right about a mild pickup in the Canadian economy and an upturn in chemical markets through the world during the next 12 months, the Canadian chemical industry still will not be solidly back on its feet. Realizing this, many Canadian chemical companies are petitioning the government to give them some relief from increasingly high and burdensome feedstock costs.

Companies in the oil-based petrochemical centers of Sarnia and Montreal are particularly hard-pressed. Among other forms of relief, they want Ottawa to exempt oil that is upgraded into petrochemicals from the petroleum compensation charge and the Canadian ownership charge. Both are up-front taxes that are written into Canada's energy pricing policies.

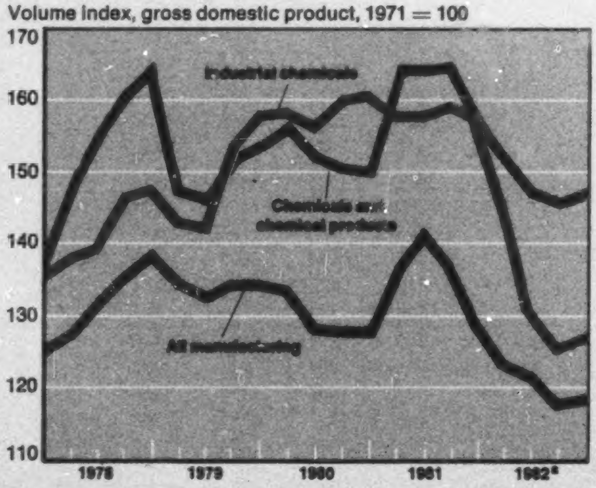
The compensation charge is the focal point. Currently, this charge, which subsidizes the cost of imported oil and domestic synthetic oil production, is $6.30 per barrel. It is scheduled to drop to $3.30 per bbl on Jan. 1, but, at the same time, the wellhead price of oil will increase $4.00.

Whether they get this relief, or any relief at all, may become known soon. Government agencies studying the problems of the Canadian petrochemical industry have just completed a task force report. The report is circulating now among the ministries and hasn't been released yet publicly.

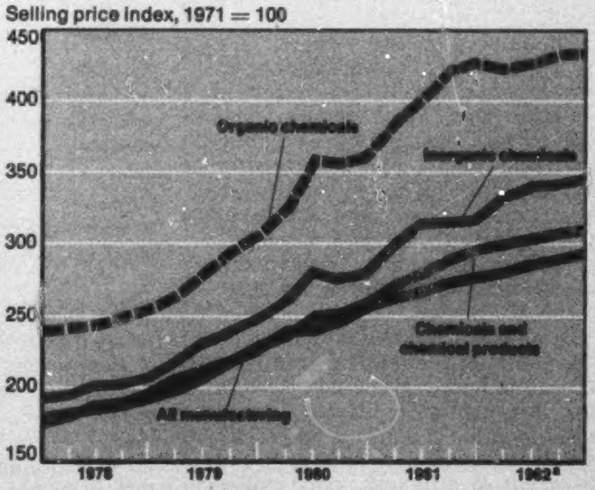
No one in the industry openly admits to having seen the report. But there are hints that it casts doubts on the costly subsidies that may be required to sustain the Petrosar and Petromont core petrochemical complexes in Sarnia and Montreal, respectively.

Whatever else the report may contain, it certainly will not provide any easy solutions to the knotty economic problems that now are facing Canada's beleaguered petrochemical industry. □

Chemical output is off sharply . . .

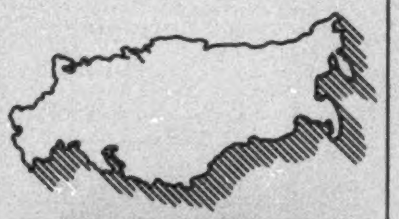


. . . and prices are climbing more slowly



a Third- and fourth-quarter 1982 are C&EN estimates. Source: Statistics Canada

Slow growth, basic problems beset U.S.S.R., East Europe



U.S.S.R./
EASTERN EUROPE

Authorities unlikely to make major changes in economic system to solve problems of chemical and other industries

Richard J. Seltzer, C&EN Washington

These are not ordinary times for the Soviet Union and its six eastern European fellow members of the Council for Mutual Economic Assistance (CMEA)—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania. The U.S.S.R. stands at a major turning point in its history, some western specialists say, comparable to the post-Lenin and post-Stalin periods.

The death of President Leonid Brezhnev leaves behind a whole agenda of unresolved problems and issues—many of them in the economic and industrial sphere.

By many accounts, the choice of Yuri Andropov to succeed Brezhnev was motivated by the desire for a strong leader and manager to get the country—particularly its economy and industry—moving again. In fact, Andropov began his service as head of the Communist Party with a speech to its Central Committee frankly acknowledging Soviet economic problems and calling for action to correct them. Measures to fight corruption and increase worker discipline are expected, for example. And Moscow, of course, sets the pattern for the region.

Information is sparse about Soviet and eastern European economic results this year and goals for next year (one western analyst comments that the worse the results, the less data the Soviets seem to publish). However, the Soviet and eastern European economies and industries generally are continuing the slower growth that began in 1979. Their [illegible] five-year plans (1981–85) set generally modest growth targets, and even many of these are not being met. This slowdown, which includes reductions in capital investment and in imports of technology and plants, reflects the bloc's economic problems and concern to reduce its foreign debt.

Thus, real gross national product for the six eastern European CMEA members actually declined in 1980 and 1981 (down 0.6% and 0.9%, respectively). Soviet GNP grew only 0.8% in 1979, 1.2% in 1980, and 1.8% in 1981, according to Central Intelligence Agency figures. (CIA growth estimates are generally lower than official national figures, because the agency tries to eliminate upward bias caused by double counting and disguised inflation.)

Similarly, industrial production for the six CMEA members dropped 2.0% in 1981, according to CIA estimates (the target was a 3.9% gain). The average was weighed down by a 14.8% plummet in Poland's output. (The other five nations increased their output 1.4 to 3.2%, all falling at least 40% short of target.) The six-nation goal for 1982 is only a 2.8% rise, but this is also unlikely to be met.

Moreover, the U.S.S.R.'s industrial output rose only 2.0% in 1981, CIA figures show, just half the goal of 4.1%. This year, Soviet output is growing at a slightly higher rate—up 2.7% through October compared to the same period last year, according to official figures (CIA calculations would yield a lower rate). However, this growth rate still falls well short of the target (4.7%). And the goal set for next year is a low 3.2%, well below the growth needed to meet the five-year plan's goal of an average increase of 4.7% per year in 1981–85. Thus, it appears that not yet halfway through the five-year plan, the Soviets already are abandoning even its supposedly moderate and realistic goals.

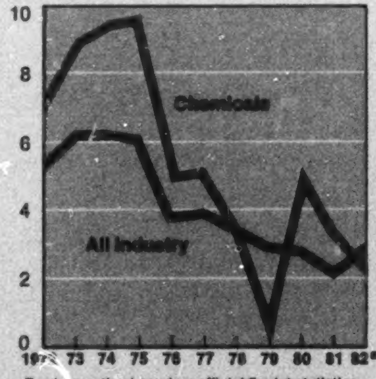
The chemical industry generally has received high priority in Soviet and eastern European development. It was among the fastest growing industries between 1976 and 1980. It also is slated to grow faster than industry as a whole in most of the region's countries between 1981 and 1985, particularly in Romania (an average annual growth rate of 10.2%, compared to 7.6% for all industry), Bulgaria (7.7% for the chemical industry and 5.1% for all industry), and the U.S.S.R. (5.7% for the chemical industry and 4.7% for all industry).

A general tendency is to increase production of plastics to substitute for metals. High growth rates also are set for synthetic fibers, pharmaceuticals, cosmetics, and other consumer products. Romania, for instance, aims to double production of synthetic rubber, plastics, tires, and pharmaceuticals between 1980 and 1985, and to increase fertilizer production 65%. The Soviet Union plans to raise output of plastics 68% between 1980 and 1985 (to 6.1 million metric tons), synthetic fibers and yarns 36%, and pesticides 40%.

However, many of the region's chemical goals appear overoptimistic. Expansion will be restricted in several

Soviet production growth has slowed since 1976

Production, % annual change



a For 10 months, based on official Soviet statistics. Note: All figures except for 1982 are based on Central Intelligence Agency estimates, giving lower results than official Soviet statistics because of postulated upward bias in Soviet figures. Sources: Central Intelligence Agency, U.S. Department of Commerce countries by limits on oil imports. Indeed, chemical production generally has been growing at a slower rate for several years and has been failing to achieve targets. Chemical and rubber output in Hungary, for example, rose only 2.0% in 1981 (the target was 4.0%) and actually dropped 2.1% in 1980. This compares with increases of 6.1% in 1979 and 10.7% in 1978. Czech chemical production rose only 0.1% in 1981, curtailed by reduced imports of oil and other raw materials. Bulgaria is an exception, racking up an 11% expansion in 1981, exactly meeting its target.

The Soviet Union raised chemical production only 3.5% last year (the goal was 5.0%), according to CIA figures. This represents a decline from growth rates of 5.2% in 1980 and 7 to 10% a year from 1971 to 1975. This year, Soviet output is slowing even more, with production through October up just 2% from the same period last year, according to official figures.

Soviet mineral fertilizer production, for example, was up only 2% through October, compared with the same period last year, whereas production grew 5% in 1981 and 12% in 1980. Output through October of sulfuric acid and plastics was actually less than in 1981 (down 1% and 0.4%, respectively). The plastics results must particularly disappoint the Soviets, because plastics are a high-priority area—output, which grew 12.5% in 1981, is supposed to rise an average 11% a year through 1985.

Chemical industry development is obstructed by many of the factors that hinder industrial development in general in the Soviet bloc—low labor and capital productivity; poor product quality; shortages of labor, energy, and raw materials; construction and transportation bottlenecks; wasteful use of resources; inefficient management; corruption; disincentives to innovate; and outmoded technology and equipment.

What will the Soviets and Eastern Europeans do about all these problems? Many western economists say the problems are rooted in the central planning system, and believe only fundamental changes in the system can solve the problems. Speculation is rife about whether Andropov will initiate changes comparable to Hungary's introduction of a measure of decentralization and market incentives. However, major changes are unlikely because they would mean a loss of political control. More likely, the region's economies will continue to limp and muddle along. □

Soviet chemical output grows more slowly than in 1981

Thousands of metric tons, unless otherwise noted	10 months 1982[a]	1981	1980
Mineral fertilizers[b]	22,300	26,000	24,760
% change[c]	2%[d]	5.0%	11.8%
Nitrogen (N)	na	10,900	10,241
% change[c]	na	6.4%	11.9%
Phosphate (P_2O_5)[e]	na	6,700	6,455
% change[c]	na	3.8%	1.7%
Potassium (K_2O)	na	8,400	8,064
% change[c]	na	4.2%	21.5%
Sulfuric acid, 100%	19,700	24,100	23,033
% change[c]	−1%[d]	4.6%	3.0%
Synthetic ammonia[f]	na	14,650	13,762
% change[c]	na	6.5%	12.1%
Plastics[g]	3,400	4,090	3,636
% change[c]	−0.4%[d]	12.5%	4.5%
Sodium hydroxide, 100%	na	2,757	2,755
% change[c]	na	0.1%	2.8%
Synthetic rubber	na	1,860	1,880
% change[c]	na	−1.1%	0.7%
Chemical fibers and yarns	1,034	1,207	1,200
% change[c]	2.0%[d]	0.6%	8.0%
Pesticides and herbicides	442	504	470
% change[c]	6.0%[d]	7.2%	−1.1%

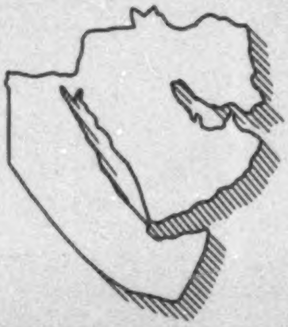
a Approximate figures. b Nutrient content basis; including some products used for technical purposes. c Increase or decrease from result in previous year. d Increase or decrease from 10-month result in previous year. e Including production of ground phosphate rock for direct application and phosphate animal feeds. f Nitrogen content. g Including resins for man-made fibers. na = not available. **Sources:** Central Intelligence Agency, Department of Commerce, Textile Economics Bureau

Drop in Poland's chemical output makes a generally poor year for East Europe even worse

Thousands of metric tons in 1981	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania
Mineral fertilizers[a]	na	1085	4787	893	2242	2640
Change from 1980	na	−8.2%	1.1%	4.7%	0.2%	7.7%
Nitrogen (N)	753	539	967	589	1274	na
Change from 1980	3.2%	−12.8%	2.5%	5.4%	−1.2%	na
Phosphate (P_2O_5)	258	340[b]	360[b]	158	866	na
Change from 1980	18.9%	−5.8%	−2.7%	6.0%	2.7%	na
Potassium (K_2O)	—	206[c]	3460	146[c]	103[c]	na
Change from 1980	—	1.5%	1.1%	0.7%	−1.9%	na
Sulfuric acid, 100%	920	1318	na	600[d]	2776	na
Change from 1980	8.0%	2.6%	na	−2.3%	−8.0%	na
Synthetic ammonia[a]	1023	na	na	na	1465	na
Change from 1980	1.4%	na	na	na	−1.2%	na
Plastics	284	913	998	311	475	580
Change from 1980	11.8%	2.1%	15.9%	−5.2%	−1.35%	0.2%
Sodium hydroxide, 100%	157	331	631	180	400	na
Change from 1980	−2.5%	1.5%	0.8%	−4.3%	−3.6%	na
Synthetic rubber	30	60	175	—	111	146
Change from 1980	0%	0%	2.9%	—	−5.9%	−2.7%
Chemical fibers and yarns	88	135	307	29	182	203
Change from 1980	2.3%	2.9%	−0.1%	0.7%	−27.1%	1.6%

a Nutrient content basis. b Including production of ground phosphate rock for direct application and phosphate animal feeds. c Imported potash added to domestically produced nitrogen and phosphate to form multinutirent fertilizer. d Including oleum. na = not available. **Sources:** Central Intelligence Agency, Textile Economics Bureau

Saudi Arabia set to emerge as factor in world marketplace for chemicals



MIDDLE EAST

First of current generation of chemical plants is expected to be on stream next year

Dermot A. O'Sullivan, C&EN London

Richard J. Seltzer, C&EN Washington

Next year marks the scheduled startup of two petrochemical operations in Saudi Arabia. Some of the methanol and urea produced will find its way into world markets.

The event will be significant on at least two counts. That the units will be ready on time is a rebuttal to those who have been skeptical that sophisticated chemical engineering projects could be built in the harsh environment of the Middle East. And it signals completion of the first of a series of projects that Saudi Basic Industries Corp. (SABIC) expects to have running before the end of 1986.

Methanol will be produced by Saudi Methanol Co. (Ar-Razi), a joint venture between SABIC and a Japanese consortium. The plant has a capacity of 1.32 billion lb a year. Urea will be made by Al-Jubail Fertilizer Co. (Samad), in which SABIC and Taiwan Fertilizer Co. are partners. This plant will have an annual capacity of 1.1 billion lb. Both the methanol and urea plants are located at Al-Jubail, the new industrial port city on Saudi Arabia's east coast, and will operate on methane derived from local natural gas.

Dow Chemical made a surprise move earlier this month when it elected to withdraw from its joint partnership with SABIC in Al-Jubail's Arabian Petrochemical Co., Petrokemya. Termination cost Dow $26 million. SABIC, meanwhile, will proceed, presumably alone, with the project, the key element of which will be an ethane cracker with an annual ethylene capacity of 1.1 billion lb. Some of the ethylene will go to a 231 million lb-per-year high-density polyethylene unit. However, Petrokemya will scratch plans for a 165 million lb linear low-density polyethylene plant. The Petrokemya cracker also will supply neighboring Eastern Petrochemical Co. with ethylene for conversion to ethylene glycol and conventional low-density polyethylene in a joint undertaking between SABIC and a group of Japanese companies.

SABIC's planners already have their sights set on the next generation of plants. According to Abdulaziz Alzamil, the state-owned company's managing director, there will be a vinyl chloride/polyvinyl chloride operation with a capacity of either 220 million or 440 million lb per year and a methyl *tert*-butyl ether plant of up to 1.1 billion lb capacity. And a 66 million lb-a-year polystyrene plant "is under active consideration." All three could be on stream by 1988.

About 11% of the output of the various units will go to local Saudi Arabian industry. A further 25% or so will be used captively by SABIC's partners. The balance will be sold on the open market. Alzamil acknowledges that such sales "will affect markets in various areas of the world, even though Saudi petrochemicals represent only 3 to 5% of world capacity." However, he insists that: "We have the right to ask that our industrial products be accorded the same liberal and unhindered treatment that we are according the products of industrialized countries. We will not accept that our products be treated unfairly, or that any obstacles be put against them."

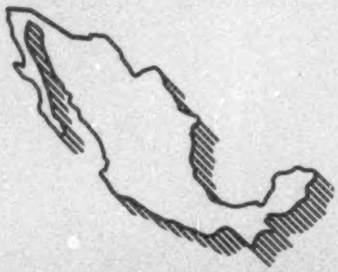
Elsewhere in the Middle East, Egyptian Petrochemical Co. is moving ahead rapidly with its plans for a petrochemical complex at Alexandria. Japan's Toyo Engineering and Technipetrol of Italy won contracts to install a vinyl chloride/polyvinyl chloride facility with a polymer capacity of 176 million lb annually. Enquiries now have gone to contractors for engineering the associated 132 million-lb chlorine unit. Completion is targeted for 1985. Eventually, a cracker will be built on the site with an initial annual ethylene capacity of 440 million lb, which might be expanded to 660 million lb, for making HDPE and linear LDPE (220 million lb), and conventional LDPE (132 million lb).

And in Israel, this year and last have been mixed years for the economy. The economy has revived from slower growth, with gross national product up about 4.5% in 1982 compared to 2.3% in 1980. The inflation rate is rising, however, and the balance of payments deficit also is increasing as a result of slackening demand for Israeli products in recession-ridden European and U.S. markets.

Despite these setbacks, Israel continues its ambitious 10-year plan for expansion of high-technology industries, viewing their high-value-added exports as the route to long-term resolution of its economic plight. Exports based on local R&D account for about a third of all industrial exports now and are to rise to half or more by 1990. Industrial exports in general (excluding diamonds) are to rise 12% a year, to $11.3 billion, by 1991. About $1 billion a year of investment will be required.

Israel's chemical industry is to raise output 8% a year and exports 10% a year through 1990. The industry accounts for almost a third of both industrial production and industrial exports—exporting about $1.1 billion last year and probably the same this year. Under the 10-year plan, $3.5 billion is to be invested in chemical development by 1990. □

Chemical expansion stalls under moves to cure Mexico's ills



MEXICO

Government measures to overcome an economic crisis have crimped chemical output and investment plans

Earl V. Anderson, C&EN New York

When an industry that had been expanding as fast as Mexico's chemical industry has the rug pulled out from under it, the ensuing fall can be devastating.

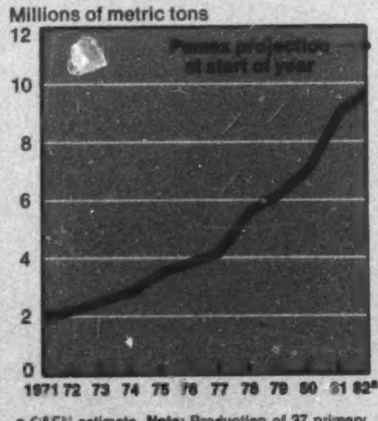
The chemical industry in that hydrocarbon-rich country had, indeed, been growing fast. Between 1975 and 1981, output of basic petrochemicals, by law the sole domain of the state-owned oil company, Petroleos Mexicanos (Pemex), had risen an average 16.5% per year.

Value of total chemical production in Mexico increased more than fourfold. Even allowing for the peso's dollar value being cut in half during that time, Mexico's chemical industry has enjoyed enviable growth.

Private investment, both domestic and foreign, poured into Mexico's secondary chemical sector. Meanwhile, Pemex embarked on a massive plant-building program that figured to reduce dramatically the country's heavy dependence on imported chemicals.

Now, however, the economic rug has been pulled out from under Mexico's high-flying chemical industry. And as a result, for most chemical companies, the game plan—at least for the short term—has switched from growth to sheer survival.

Petrochemical output falls short of target this year



a C&EN estimate. Note: Production of 37 primary petrochemicals produced exclusively by Petroleos Mexicanos (Pemex). Source: Pemex

Much will depend upon the policies implemented by Miguel de la Madrid Hurtado, who was sworn in earlier this month for a six-year term as Mexico's new president. In his inaugural address, de la Madrid said that he soon would embark on a program of tough austerity measures to deal with Mexico's worst economic crisis in 40 years.

If he does, the chemical industry—indeed, all of Mexico's industry—is in for at least one lean year, probably more. If he doesn't, the economic outlook could be even more bleak.

De la Madrid takes over a country whose economy, until this year, was the envy of the world. But growth depended upon revenues from Mexico's huge oil reserves, and the bottom has fallen out of the world oil market. Mexico's foreign debt soared to $80 billion. The country now finds itself with little foreign exchange to pay the interest, much less the principal, on that debt.

Two devaluations this year shrunk the value of the peso from about 25 to the U.S. dollar to an official 70 to the dollar. Unofficially, the exchange rate is above 100 to the dollar. Inflation in Mexico is running about 100% annually. Unemployment is high and will go higher, even without necessary government austerity measures. Former president Jose Lopez Portilio imposed tight controls on foreign exchange that make it difficult, if not impossible, to get critical imports. The banks throughout the country have been nationalized.

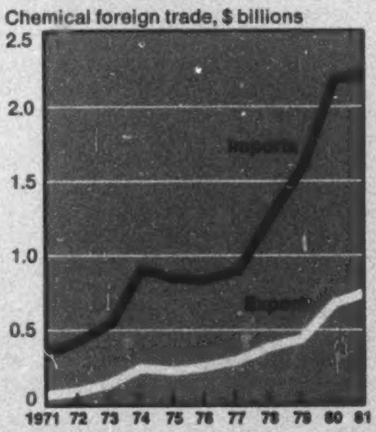
Under these circumstances, it isn't surprising that Mexico's chemical industry is struggling. Chemical output was up through the first half of the year, but has dipped badly since August. Pemex, which had expected to produce about 11.4 million metric tons of basic petrochemicals this year (a 24% increase), probably will make only 9.9 million tons, about 87% of the target.

A spokesman for a U.S. company with a subsidiary in Mexico says that by July that subsidiary had reached 80% of its 1982 sales goal. Now, he doubts that the subsidiary can even reach its goal.

Pemex has delayed some of its ambitious expansion plans for petrochemicals. Others may be canceled completely. Private companies in the secondary chemical industry also have put many of their expansion plans on hold.

The entire Mexican chemical industry, in fact, will be on hold until de la Madrid can put Mexico's economic house back in order. □

Chemical trade deficit nears $1.5 billion



Source: Asociación Nacional de la Industria Quimica (ANIQ)

Demand for chemicals stagnates but import curbs and exports boost output

BRAZIL

With new capacity coming on stream, Brazil's chemical industry will have to strive even more to build foreign sales

Earl V. Anderson, C&EN New York

The Brazilian chemical industry, like its counterpart in Mexico, is a victim of its country's broader economic plight. In Mexico, however, the necessarily harsh economic moves dictated by a huge foreign debt came suddenly, painfully, and only recently.

Brazil also is saddled with a huge foreign debt, estimated variously from $72 billion to $90 billion. But in Brazil the government has been making all of the proper moves for the past two years to cope with its external financial problems.

Anticipating the impact of the recession and high interest rates throughout the world, Brazil freed interest rates and cut its budget deficit. It also set in motion small and frequent devaluations of the cruzeiro to keep its industries competitive.

The impact was inevitable. After chalking up several successive years of impressive growth, Brazil's real gross domestic product fell 2% last year. It certainly won't improve this year, or next year either.

Most Brazilian chemical executives suspected early last year that the industry's short-term outlook wasn't too bright. Events have borne them out.

Chemical and petrochemical sales dropped last year 7.8%, after recording an 18.7% surge in 1980. Average industry profit margins (as a per cent of sales) dipped to 4.5%, compared to 6.4% a year earlier.

More of the same is in store for the Brazilian chemical industry this year and next. First-half production statistics compiled by Abiquim (Associacão Brasileira da Industria Quimica e de Produtos Derivados) indicate that output of many chemicals is way ahead of last year. Notable exceptions are caustic, chlorine, and low-density polyethylene.

These statistics, however, can be misleading. They do not reflect a strong domestic market for chemicals in Brazil. Instead, they are industry's response to the government's determined effort to improve Brazil's balance of trade by restricting imports and promoting exports.

According to one Brazilian chemical executive, chemical demand in Brazil will be flat to down 10% in 1982. Market growth in 1983 will be zero, he adds.

Certainly, exports coupled with the substitution of domestic output for imports will be major factors in any production increases in 1983. A few months ago, the government added another wide list of chemicals that cannot be imported. That and recent official statements indicate that import restrictions will be even more severe next year.

Brazilian chemical exports jumped last year to about $400 million from $148 million in 1980. First-half statistics indicate that chemical exports will be about the same in 1982. However, many companies have had to sacrifice profits to move these products out of Brazil and into highly competitive world markets.

One thing is certain. Brazil will have more chemicals to export in 1983. Domestic demand will remain stagnant. Meanwhile, the country's newest petrochemical complex at Rio Grande do Sul will be producing more—and currently unneeded—chemicals. □

Output rising for most chemicals

Thousands of metric tons	First six months 1982	First six months 1981	% change	Annual capacity
INORGANIC CHEMICALS				
Ammonia	492	216	127%	962
Chlorine	242	308	−22	762
Sodium hydroxide	374	396	−5	876
Sulfuric acid	1174	1022	15	3242
ORGANIC CHEMICALS				
Benzene	168	168	0	326
Ethylene[a]	386	369	5	776
Ethylene oxide	63	44	44	140
Formaldehyde	76	69	11	292
Methanol	55	55	0	158
Propylene	226	222	2	574
Styrene	98	86	14	230
Toluene	69	60	14	122
Urea	151	133	13	841
Vinyl chloride	138	109	26	290
Xylene	48	43	13	80
PLASTICS				
Polyethylene, high density	67	58	15	120
Polyethylene, low density	167	170	−1	312
Polypropylene	74	56	32	100
Polystyrene	55	38	46	180
Polyvinyl chloride	141	136	4	375

[a] Petrochemical only. Source: Associacão Brasileira da Industria Quimica e de Produtos Derivados

JANUARY 3, 1983

CHEMICAL & ENGINEERING

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ACS President
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Cover: Photo by Greg Pease

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JANUARY 3, 1983

News of the Week

- **Oil prices seem destined to fall, but repercussions are bound to be negative as well as positive. Page 6**
- **Italian government to become sole owner, through ENI, of Enoxy Chemical as Occidental sells its share. Page 7**
- **Burlington's takeover bid for El Paso exceeds $600 million, but the bidding isn't over yet. Page 7**
- **Nuclear Waste Policy Act of 1982 secures the House's approval by a wide margin. Page 7**
- **FMC Corp.'s landfill in Minnesota tops EPA's list for having the most hazardous waste site. Page 8**

Business

U.S. amino acids producers boost market previously dominated by imports, balance commodity and specialty products. **Page 18**

Upjohn fills niche with introduction of Isoplast, a new engineering impact-resistant plastic with potential for wide-ranging use. **Page 20**

International

International network of chemists organized by UNESCO for exchange of services and information. **Page 21**

Petrochemical industry in Canada's Maritime Provinces seen as bright light with new sources for hydrocarbon feedstocks. **Page 24**

Government

Congress says happy new year to federal agencies with R&D funds generally higher than Administration's requests. **Page 27**

Science

New multiple quantum NMR simplifies study of molecules oriented in space, easing interpretation of their spectra. **Page 30**

Education

Industry and academia join forces to ponder the problems and opportunities of corporate interest in campus research. **Page 32**

Technology

Chemical engineering data on compounds are being gathered by institute for centralized storage and dissemination. **Page 34**

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News Focus

Fire safety research focuses on the effects of toxic gases from burning plastics in building fires. Page 9

Capacity Jumps for Amino Acids

New U.S. producers are moving into the market, estimated at $1.2 billion in 1982, but Japanese are still dominant force

Patricia L. Layman, C&EN London

The U.S. amino acids market, which up to now has been chronically dependent on imports, is taking on more of an American accent. W. R. Grace is now bringing on stream its new plant in Deer Park, Tex., to produce glycine and other amino carboxylic acids. The firm also plans to devote much of the new $3.1 million fermentation pilot plant in Columbia, Md., to produce pharmaceutical-grade amino acids.

Moreover, earlier this year in Raleigh, N.C., the Japanese manufacturer Ajinomoto brought on stream a $37 million plant for making a variety of amino acids. And another Japanese firm, Kyowa Hakko, plans to build a plant for producing lysine at Cape Girardeau, Mo., within the next several years.

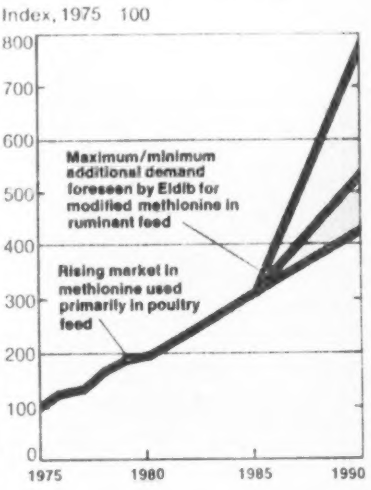
Up until these producers decided to enter the U.S. production scene, the amino acids business had been a two-sided market. U.S. producers have, indeed, been represented in the amino acids business, but in the commodities end of it, primarily with methionine. The other side—specialty amino acids—has nearly all been imported. But the market is becoming increasingly global, for both commodity and specialty products, and most observers agree that competition is heating up.

The current demand outlook gives some reason for the plant investment spurt, although U.S. capacity got way ahead of demand in methionine. For the next half decade, consultants and producers put annual physical demand growth in the U.S. on the low end of a 7 to 10% range worldwide. The highest growth could be in developing countries, where the market is just now being tapped. In 1982, total worldwide sales volume was 455,000 metric tons valued at $1.2 billion, by estimates from London-based consultants L. Hepner & Associates.

There has been one casualty in the U.S. buildup to serve this growing market. Early in 1982, Du Pont withdrew from the methionine business, closing its Beaumont, Tex., plant operations, which had been producing methionine since 1954. Du Pont was faced with a fairly stable market of probably about 115 million lb per year, supplied by three U.S. producers—itself, Monsanto, and the U.S. affiliate of the West German firm Degussa—and by importers. At that time, Monsanto was bringing on stream its new plant for methionine in Chocolate Bayou, Tex., with a capacity of 100 million lb per year, with provisions for expansion. Imports continued to be a persistent factor in the market. Hence Du Pont's decision to exit the business (C&EN, Feb. 8, 1982, page 22).

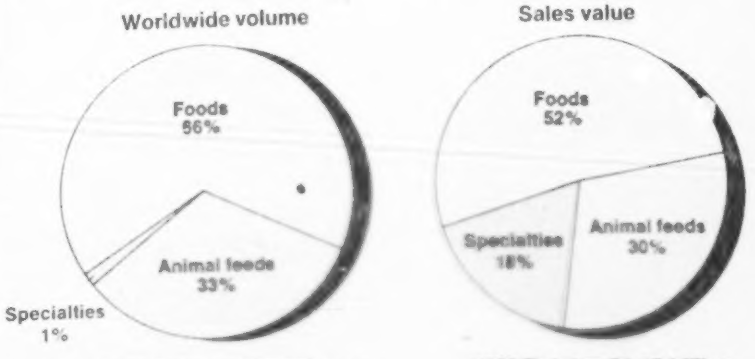
Even with the domestic entries into U.S. production, though, the worldwide picture remains dominated by Japanese producers, with Ajinomoto the largest. There probably exist fewer than 20 producers of amino acids worldwide. About half of those are Japanese firms, and the others are scattered throughout the rest of the world.

U.S. methionine market could balloon in 1980s



Source: Eldib Engineering & Research

Specialties' share of amino acids value is disproportionate



1982 Total = 455,000 tons

1982 Total = $1.15 billion

Source: L. Hepner & Associates (London)

Common amino acids fall into seven broad classes

I. **Aliphatic amino acids**
- Glycine
- Alanine
- Valine[a]
- Leucine[a]
- Isoleucine[a]

II. **Hydroxyamino acids**
- Serine
- Threonine[a]

III. **Dicarboxylic amino acids, amides**
- Aspartic acid
- Asparagine
- Glutamic acid
- Glutamine

IV. **Amino acids with basic functions**
- Lysine[a]
- Histidine[b]
- Arginine

V. **Aromatic amino acids**
- Phenylalanine[a]
- Tyrosine
- Tryptophan[a]

VI. **Sulfur-containing amino acids**
- Cysteine
- Cystine
- Methionine[a]

VII. **Imino acids**
- Proline
- Hydroxyproline

a Essential amino acids: the human body cannot make them. b Also could be classified in group V.
Source: Mahler & Cordes, *Biological Chemistry*, 1966

The major reason for the Japanese technological and market dominance goes back to the development of that modest but effective food enhancer, monosodium glutamate. MSG can be extracted from soy sauce, which is rich in amino acids. Indeed, "all producers of MSG are potential producers of amino acids," says Andrew Eldib, president of Eldib Engineering & Research, a consulting firm based in Berkeley Heights, N.J. "Many are flirting with the idea; they just need the courage to take the risk."

A number of sizable risks confront new companies entering the business. Foremost among these, industry marketers say, is that little is known about Ajinomoto's technology and manufacturing costs. Says one marketer, "Nobody knows how much it costs Ajinomoto to make amino acids. Maybe they could drop the price to half of what it is—who knows?" That kind of uncertainty tends to give second thoughts to corporate officials contemplating major commitments to a market.

Additionally, the fastest-growing markets for amino acids—for use in pharmaceuticals or in nutritional formulations for intravenous solutions, for example—are the markets most difficult to enter, because of government regulations. "All those amino acids in the high-priced level must be approved by the Food & Drug Administration for pharmaceutical use," says Eldib. "That means big dollars, and the Japanese and French already have approval."

Again, that tends to discourage marketers from making major outlays for R&D to bring on stream products sold in small volumes. The $37 million Ajinomoto plant in North Carolina, for example, is slated to produce "several hundred" tons of amino acids annually. That is a typical volume for most amino acids, except for glutamic acid-derivative MSG, methionine, and lysine, which come close to or top 100,000 tons per year in demand worldwide. The fourth-largest worldwide demand, for cysteine, is probably about 1000 tons per year.

Most companies contemplating entering the market are looking at it "for the wrong reasons" and are "ignoring the dominance the Japanese have in the industry," insists Leo Hepner, a principal of L. Hepner & Associates. In the U.S., in particular, he adds, most companies would have to start from scratch to develop specialized technology and specialized lines of products, with a concommitant "tremendous capital expense, to make a few tons."

Companies that have a promising future in the field, Hepner adds, have some background in at least the chemistry relating to amino-acid synthesis, such as cyanide chemistry.

Cyanide chemistry is proving Grace's entree into the business. Through its Hampshire Chemicals unit at Nashua, N.H., Grace had a background of cyanide-based amino-acid chelating agents—nitrilotriacetic acid, for example, and ethylenediaminetriacetic acid. From there, the company has branched out

Medicinal feed additives make $1 billion market

Amino acids are an important part of the market for animal-feed additives, but just medicinal additives for animal feed is a market estimated to be worth roughly $1 billion per year. Sales are dominated by three U.S. producers—Eli Lilly, Pfizer, and American Cyanamid. Together, they account for more than 65% of the market, with the remainder shared by another 20 or 30 companies. The U.S. accounts for 50% of the demand for animal feed additives, with Western Europe accounting for 30%. However, Europe and the developing countries are rapidly overtaking the U.S. Those are the conclusions of a recent study on medicinal animal feed additives from L. Hepner & Associates, a consulting company based in London.

Among the reasons the largest market share is held by the U.S., according to Hepner, is that regulatory officials there permit use of combinations of antibiotics—two or three in a single formulation. That is not permitted in Europe. Nor are high dosages—typically 200 ppm in the U.S., compared with the 20-ppm average seen in Western Europe. American agriculture also places a greater dependence on intensive farming—feeding cattle in feedlots, for example. That permits easier dosing with feed than, say, the pasture-grazing feeding still more common in Europe, Hepner suggests.

Growth promoters to accelerate absorption of feed from an animal's rumen have proved to be one of the fastest growing segments of the business during the past decade. Manufacturers also have branched out from antibiotics for humans, such as penicillin and tetracycline, to develop antibiotics especially for animals, to keep them healthy and growing and to treat disease. Those are the major changes in the animal feed industry over the past decade, the study concludes.

Many other facets of the business remain the same. It is still a competitive, almost cutthroat business, as formulators buy from an eager group of additive suppliers competing both on specific products and on development of new ones. As Hepner observes, "Feed is already a significant portion of the costs of raising an animal. How much better will another additive make it?"

into glycine, the simplest amino acid; sarcosine; and iminodiacetic acid (an intermediate), before it decided to build a plant for those compounds, among others, at Deer Park.

"We always talked about amino-acid chelating agents, amino polycarboxylic types," says Edward G. Najjar, executive vice president of Grace's organic chemicals division, based in Lexington, Mass. "But more recently, people have been talking about amino acids as a specific type, the building blocks to produce proteins." Glycine, he says, fit right in with that trend. Not only is it a chelating agent, but it is a key protein amino acid, for pharmaceuticals and nutritional products, for example.

"With the onset of the pharmaceutical market, there was a need for a U.S. source of the amino acids," Najjar adds. "We were encouraged by people to do this, even before Ajinomoto announced its plans to put up a plant in Raleigh. We had unique technology to make glycine," so the company decided to get in, looking for niches in specialty products and avoiding the commodity areas of methionine and lysine.

Synthesis, fermentation, and extraction from natural products—for example, cysteine from human hair or amino acids extracted from sugar-mill and leather-mill waste streams by ion-exchange chromatography—remain the major production techniques. Biotechnology probably will not revolutionize the business as much as make it more efficient by: allowing fermentation routes to amino acids that now are made by chemical synthesis, for example; using microorganisms to optimize the resolution of isomers or speed up a particular reaction; or using immobilized enzymes in dipeptide synthesis, perhaps.

Few of these schemes are aimed at commodity markets. Unless new fermentation routes could enable methionine to be produced at less than the $2.00 to $3.00 per kg it now costs, few potential customers would be interested. On the other hand, if production costs could be brought down enough, it might create enough demand to make full-blown commodities out of some of the specialties. For example, if a production route to tryptophan could be found so that present selling prices as high as $110 per kg could be slashed to $5.00 or $10, price-conscious compounders of animal feeds might be interested enough to put it in their bulk products.

However, most producers of specialty amino acids have their eyes on finding new markets, or getting in on the rise of ones just starting. A key market—though not a new one—for amino acids is the parenteral solutions market. These products are a third generation of fluids used to nourish the ill by intravenous or nasal-gastric feeding. Glucose was the first nutrient followed by protein hydrolysates, for example, casein hydrolysates, which had a mixture of racemic amino acids. The development of technology for producing the preferred levo form spurred the market into its third phase: It hit $30 million in 1979 and, by one estimate, probably is approaching $50 million in 1982.

Even that market faces a limit, however. There are only so many people who each year become ill enough to require such fluids. On the other hand, there is still a seemingly inexhaustible business being done in low-calorie sweetening, and amino-acid sweeteners seem poised to make the best of that. The patents covering aspartame, the major contender, are tightly held by Ajinomoto and Searle, but some industry marketers predict that, given a relative shortage of the two amino acids used to make the compound, phenylalanine and aspartic acid, other manufacturers will jump in despite the patent situation.

Peptide research is a major outlet for R&D interest in amino acids, suggests consultant Eldib. Promising areas are peptides for both male and female oral contraceptives, for diabetes treatment, and for treatments for angiotension. Such sophisticated technology or derivative chemistry could help lessen a tendency for amino acids to fall into selected specific markets—an eggs-in-one-basket problem. □

Upjohn offers new engineering plastic

An engineering resin-grade thermoplastic polyurethane has been introduced by Upjohn Co. under the tradename Isoplast that the firm expects to compete in certain niches against other engineering plastics. Company spokesmen decline to reveal the chemical nature of the resin, other than that it is an inherently impact-resistant polyurethane glass based on methylenediphenyl isocyanate (MDI). Separation of incompatible polymer segments impart impact resistance as well as give the material a milk-white, opaque appearance, which contrasts with that of transparent, amber polyurethane rubbers.

Upjohn will market the new resin through its CPR Division, Torrance, Calif. Production will continue for now on a pilot-plant scale at the firm's research center in North Haven, Conn., which developed it. Prices are from $1.90 to $2.10 per lb.

Processing is by injection molding or extrusion, with machine barrel temperatures profiled from 430 to 440 °F and a melt temperature of 450 °F. Water absorption of processed resin is only 0.17% in 24 hours, which is superior to that of some nylons, but the resin is sensitive to moisture degradation in processing. The company recommends drying to a moisture content of less than 0.03% before use.

Company spokesmen say the resin has very good resistance to abrasion, chemicals, solvents, fuels, and oils. Molded parts and extruded profiles turn yellow on long exposure to sunlight, but physical properties are said to be unimpaired.

Upjohn marketing managers see outlets for the plastic in mechanical and electrical parts for industrial, agricultural, and mining equipment; automotive interior and exterior parts; and sporting equipment.

Upjohn managers indicate that the company will make further entry into engineering plastics markets in 1983 with the introduction of thermoplastic copolyamides based on reaction of MDI and perhaps toluene diisocyanate (TDI) with azelaic, adipic, and isophthalic acids. The firm has marketed a thermoplastic polyimide for about 10 years. □

JANUARY 17, 1983

CHEMICAL & ENGINEERING

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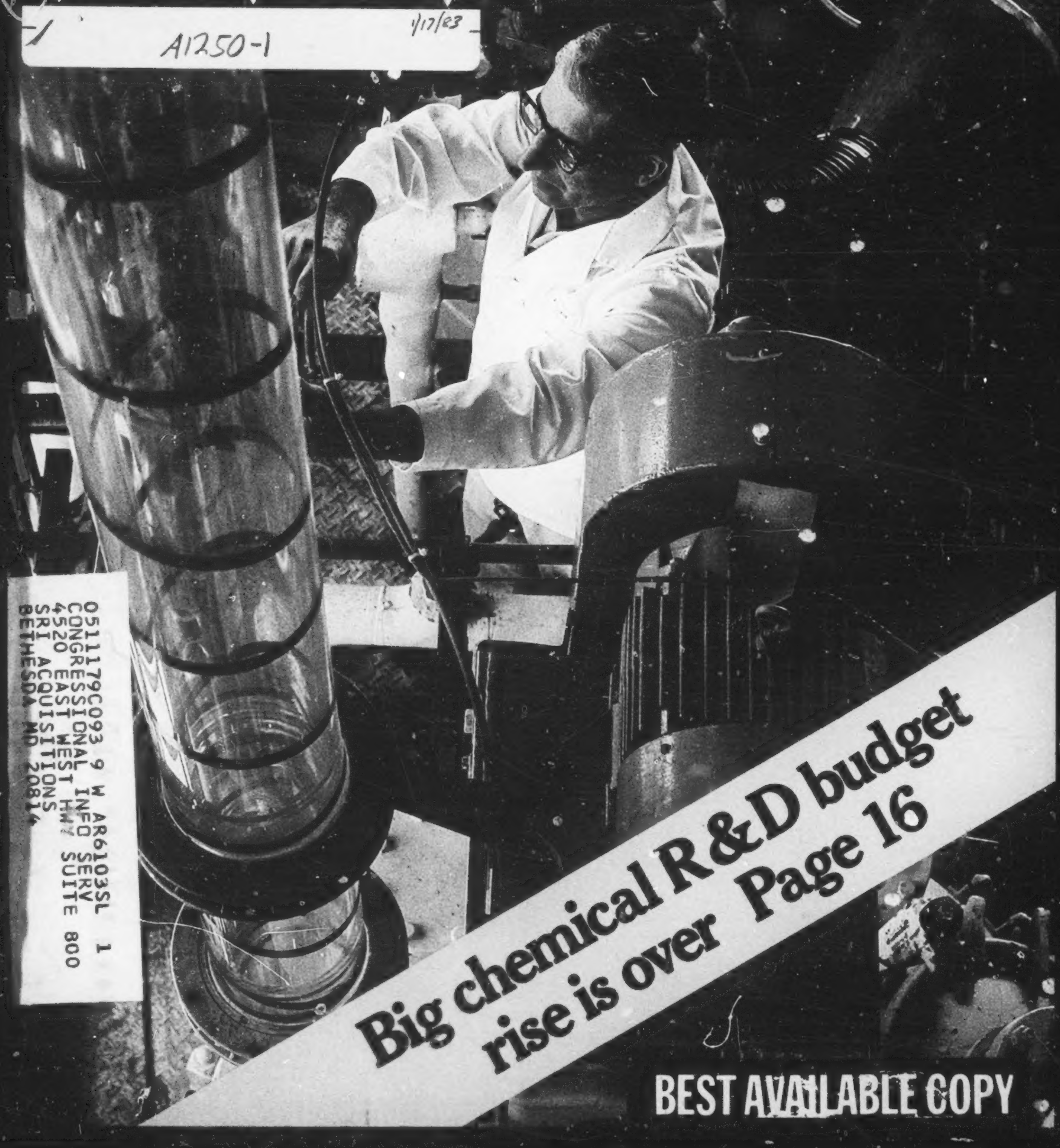

Big chemical R&D budget rise is over Page 16

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Cover: Medicinal research pilot plant at
Pfizer's research center, Groton, Conn.

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- **OSHA ordered by court to issue an emergency health standard on ethylene oxide. Page 9**
- **U.K. proposal to install nuclear power plant elicits outcries of protest. Page 9**
- **Engineering education in the U.S. beginning to improve, following call-to-arms last spring. Page 10**
- **Puerto Rico's Corco finally bites the dust, after years of struggle and bankruptcy. Page 10**

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New Congress marked by rules changes and committee shakeups in the House, where strong Democratic majority reigns. **Page 24**

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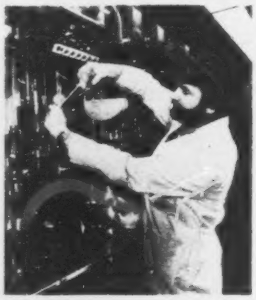
Education

Chemistry graduate students still need to know a foreign language; engineering programs struggle with accreditation. **Page 44**

Technology

Resistance to alkali makes glass fiber from waste slate and limestone a good reinforcer for cement. **Page 47**

Fluorinated surfaces found to aid bonding of diamonds to metal, resulting in extremely hard grinding wheels. **Page 48**



Cover Story

U.S. basic chemical companies anticipate a much slower rate of R&D spending in 1983 compared to 1982. Page 16

Chemical Firms Will Reduce R&D Spending in 1983

U.S. basic chemical companies anticipate only 5% hike in R&D funding in 1983 after boosting spending 13% last year

William J. Storck, C&EN New York

The recession in the U.S. chemical industry finally seems to be taking its toll on research and development spending among major companies. Current plans among 15 large basic chemical firms surveyed by C&EN call for spending to be up only 5% this year, to a combined total of $1.99 billion, after a 13% rise in 1982.

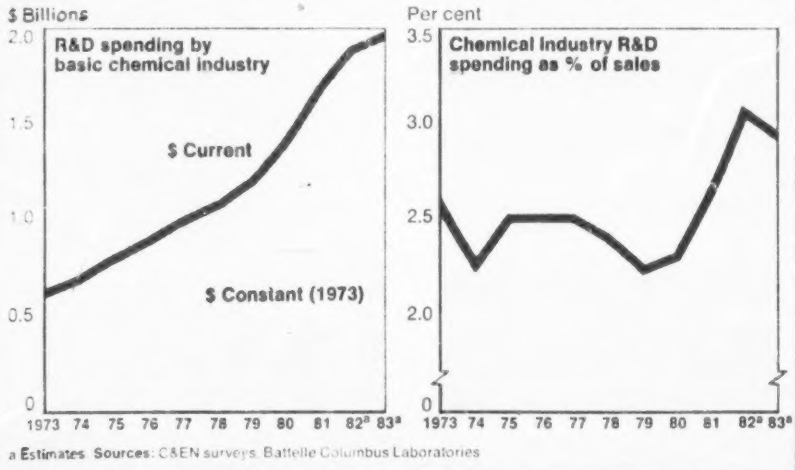
In the depths of the long-running recession, future-oriented spending is getting a close look at all companies. For instance, plans for capital spending show a marked decrease in 1983 after similar lower spending levels in 1982 (C&EN, Dec. 13, 1982, page 17).

R&D spending has resisted that pattern, having held up fairly well in 1982 and increasing again in 1983, although not by much. But 1983 will break a long string of healthy R&D spending increases. This year, for only the second time in a decade, R&D spending will grow less than 10% from the previous year. The other time within a decade was in 1978, when R&D spending was up 7% from the year before.

It is only natural to blame the economy. With chemical industry sales off more than 7% from last year and earnings off more than 30%, chemical industry executives are closely examining R&D spending as well as other budgets. Last year, Stauffer Chemical chairman and chief executive officer H. Barclay Morley told C&EN in an interview that, given the economic climate, he could not recommend very much growth in any of the company's budgets for this year (C&EN, Nov. 8, 1982, page 14).

This attitude seems to be pervasive in the industry. In its survey of these 15 chemical companies, C&EN found that although the R&D budget will decline this year at only one company, three more firms will hold funding at 1982 levels, and an additional four will hold increases to 5% or less. Thus, eight of the 15 chemical companies surveyed probably will spend less on R&D, adjusted for inflation, in 1983 than they did in 1982.

R&D budget rises will about match inflation in 1983... ...and will drop as a per cent of corporate sales



a Estimates. Sources: C&EN surveys, Battelle Columbus Laboratories

As the recession deepened during 1982, chemical companies scaled back their R&D spending plans. Originally, 13 of the companies on both this year's and last year's list had slated spending of $1.91 billion. However, by the end of 1982, actual spending is estimated at about $1.81 billion, or 5% less than originally budgeted.

Still, in spite of the cutback in 1982, the 15 chemical companies surveyed this year by C&EN finished 1982 with R&D spending increasing to $1.90 billion, 13% more than in 1981. Most of the companies surveyed maintained healthy increases last year, but two—Celanese and Diamond Shamrock—decreased R&D spending. Celanese spending fell almost 4% from 1981 to $100 million; and Diamond Shamrock spent $47 million, down 11% from the year before.

For this year, Celanese is budgeting its R&D spending at about the same pace as in 1982, but Diamond Shamrock will allocate 2% less, to about $46 million. Diamond Shamrock, though, has transferred some of its R&D spending to a joint venture, so that its R&D effort is greater than the budget figure reflects.

This year's 5% increase for all 15 firms means that in terms of real-dollar spending, there won't be much of an increase in 1983. Battelle Columbus Laboratories estimates that

Companies will halt string of big R&D spending increases in 1983

$ Millions	Worldwide R&D spending Planned 1983	Actual 1982	Planned 1982	1981	1980	1979	1978	1977	Change from previous year 1983	1982	R&D spending as % of sales 1982	1981
Air Products	$ 40	$ 37	$ 35	$ 32	$ 30	$ 24	$ 23	$ 24	8%	16%	2.4%	2.0%
Allied	186	186	190	152	105	70	56	51	0	22	2.9	2.4
American Cyanamid	200	180	180	164	142	124	108	96	11	10	5.1	4.5
Celanese	100	100	118	104	94	92	83	77	0	−4	3.3	2.8
Diamond Shamrock	46	47	64	53	45	37	32	26	−2	−11	1.4	1.6
Dow Chemical	480	455	525	404	314	269	232	203	5	13	4.2	3.4
Ethyl	39[a]	38	b	37	34	29	25	28	3	3	2.3	2.1
W. R. Grace	71	59	65	55	45	42	37	32	20	7	1.0	0.8
Hercules	68	67	66	61	53	47	40	37	1	10	2.7	2.2
Monsanto	284	264	260	221	204	161	136	132	8	19	4.2	3.2
Olin	48[a]	45	b	39	31	26	25	25	7	15	2.5	1.9
Pennwalt	34	30	34	27	24	22	23	21	13	11	3.1	2.6
Rohm & Haas	94[a]	91	90	77	67	54	49	45	3	18	4.9	4.1
Stauffer Chemical	64	60	62	51	44	37	34	33	7	18	3.9	3.0
Union Carbide	238	237	222	201	166	161	156	156	0	18	2.7	2.0
TOTAL	**$1991**	**$1896**	**$1911[c]**	**$1678**	**$1398**	**$1195**	**$1059**	**$986**			**3.1%**	**2.6%**
ANNUAL CHANGE	**5%**	**13%**	**19%[c]**	**20%**	**17%**	**13%**	**7%**	**11%**				

a C&EN estimate. b Not included in previous survey. c Excluding Ethyl and Olin.

inflation affecting R&D in 1983 will be about 4.2%. Thus, the increase of real-dollar R&D spending for 1983 will be only slight.

This bodes rather ill for R&D employment next year. Because the major part of R&D spending is for people, a flat year for budgeting means little or no expansion of R&D staffs.

A spokesman for W. R. Grace, for instance, says that when that company recruits on campuses for people for R&D, it meets very little competition from other chemical companies.

W. R. Grace has budgeted the biggest increase in R&D spending among the companies surveyed. Grace says that its spending will rise about 20% in 1983 to $71 million. Some of this money is going into a biotechnology effort. Grace has said that it will spend about $50 million over the next five years on biotechnology research.

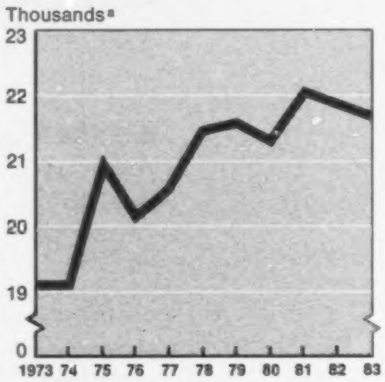
Only two other companies have budgeted increases of more than 10% for this year. Pennwalt says that it will increase spending about 13% from last year to $34 million. And American Cyanamid plans to spend about $200 million, 11% more than last year.

With R&D budgets increasing only about 5% this year, R&D as a percentage of company sales probably will decline. If the chemical industry begins its recovery this year, sales almost certainly will rise faster than the 5% increase slated for R&D. Thus, R&D spending as a percentage of sales will drop from 1982's 3.1%. The 1982 percentage, however, is artificially high because, at the same time that R&D spending was rising, sales among chemical companies were dropping. This accounts for much of the increase in the ratio of 3.1% from just 2.6% in 1981.

For years, R&D spending in the chemical industry has been rising healthily. Between 1972 and 1982, R&D spending at the 15 companies surveyed has increased at an average annual rate of 12.5%, and for the past five years, the increase has averaged 14% annually. So, a 5% increase this year doesn't look like much.

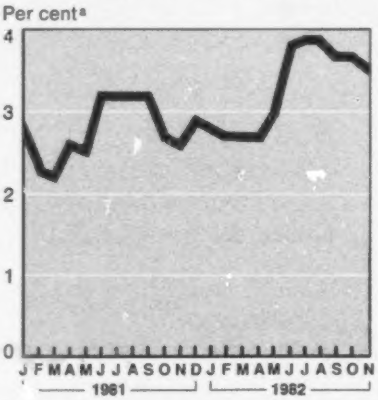
However, R&D spending probably won't stay down forever. Most of the companies surveyed say that they are merely on hold until they are sure of an economic recovery. Then, the feeling is that spending for R&D once again will begin to match its historical growth. □

Companies put brakes on professional R&D staffs . . .



a Full-time equivalent R&D scientists and engineers in basic chemical industry at beginning of year. **Sources:** National Science Foundation, C&EN surveys

. . . as technical professional unemployment stays high



a Unemployment rate for professional and technical white-collar workers. **Source:** Bureau of Labor Statistics

R&D group that is disproportionately large by industry standards compared to the scale of our commercial operation."

The sale will not include Ring Around Products, a Zoecon subsidiary that specializes in seeds. That operation, which has performed poorly over the past two years, likely will be sold separately by Occidental. However, Diekman points out, Sandoz owns two U.S. seed companies and a Dutch seed company. Therefore, he says, Zoecon's research into genetic engineering with the goal of improved seed varieties will have a commercial outlet within the organization.

Occidental purchased Zoecon in 1977 for about $50 million. The sale of Zoecon and other Occidental assets is part of an effort to reduce the company's debt load that was incurred in the $4-billion acquisition of Cities Services in 1981. Ring Around was acquired shortly thereafter to diversify Zoecon into areas less heavily regulated than pesticides. ☐

Ink business poised to pick up again

The U.S. ink business surpassed $250 million in shipments in 1962, $500 million in 1972, and $1 billion in 1979, according to the Commerce Department. A recent consulting report says that shipments hit about $1.4 billion in 1982 and will be $1.7 billion in 1987.

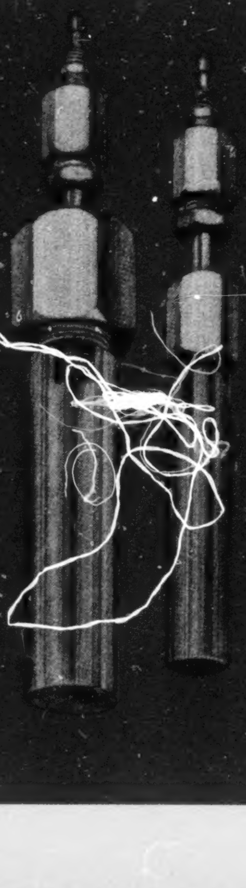
The only trouble with such apparent expansion, says Business Communications Co. of Stamford, Conn., is that nothing happened last year. "An industry tradition was broken," the consultant firm says. "Up until 1982, the printing ink industry experienced a consistent annual growth rate of about 5%."

The pause won't last long, however. For 1983 through 1987, the firm predicts that inks will pick up steam again at close to their traditional growth rate. That's not bad for a chemical product line these days, since most are forecast to grow more slowly in the 1980s than in the past two decades.

If it weren't for one problem market, inks would fully match their past growth rate in the 1980s. The trouble is in letterpress use, which Business Communications shows losing ground at 4.6% per year through 1987. This would pull down letterpress ink shipments' value from $125 million in 1982 to $100 million, and would decrease market percentage from 9% to 6%.

Otherwise, all other major outlets will move along at a rate of at least 5% per year, the company predicts. That goes for the largest use in lithographic offset printing, 39% of the total market in 1982 at $530 million. A renewed pickup at an average 5.0% per year through 1987 will put this market at $680 million.

The fastest growth will come for the second largest ink use—in gravure printing, which accounts for 23% of the total business at $310 million in 1982. Ink use for gravure printing will grow 6.5% per year



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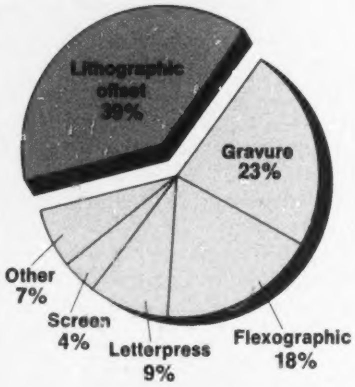
CIRCLE 64 ON READER SERVICE CARD

Largest ink market is lithographic offset



Total 1982 U.S. shipments = $1.36 billion

Source: Business Communications Co.

through 1987, the firm forecasts, when value will hit $425 million.

The other major use area is in flexographic printing, for which ink shipments are due for 5.3% annual growth from $250 million in 1982 to $325 million in 1987.

Sidelights of the Business Communications report on the ink business include items such as inks' use of raw materials—1.3 billion lb in 1982 worth about $750 million—and inks' share of raw materials costs in their major outlets—just 2 to 8% generally, except for nearly 20% in gravure printing. □

Outlook bright for sweetener raw material

Growth prospects for the synthetic sweetener aspartame are as high as the sky, and that means L-phenylalanine's are, too, according to one market research firm. L-Phenylalanine is one of the major raw materials of the G. D. Searle & Co. sweetener, now entering its third calendar year as a commercial product in the U.S.

According to a new study by Eldib Engineering & Research of Berkeley Heights, N.J., annual U.S. sales of L-phenylalanine, an essential amino acid, will rise from $2.5 million in 1982 to $77 million in 1987 for an average annual growth rate of almost 100%. Over the same span, the report says, aspartame demand will reshape L-phenylalanine's end-use market radically: Medical and nutritional applications, which account for more than 99% of annual sales now, will make up only 6% in 1987, despite solid growth. Aspartame will account for the rest.

There is a fly in the ointment, however—supply. As the Eldib report points out, the processes available to make L-phenylalanine (the isomer needed to make aspartame) are concentrated in the hands of the big Japanese amino acid producers, Ajinomoto, Kyowa Hakko, and Tanabe. All use a fermentation process that yields a product laden with impurities. Andrew Eldib, president of the research firm, notes that the purification process is elaborate and accounts for a significant part of the current cost of producing the amino acid.

In addition, the fermentation route is relatively slow and yields relatively fixed amounts of the product compared to the total volume of liquor. There are substantial recovery and waste disposal problems using this process.

"The Japanese companies are saying that with the fermentation process there are so many by-products, they must get away from it," Eldib says.

Where the Japanese and others interested in producing L-phenylalanine will go, the Eldib study predicts, is into synthetic production. Synthetic processes, starting from benzaldehyde and acetic acid, yield fewer impurities. On the other hand, they also yield DL-phenylalanine, from which the L isomer must be recovered. Nevertheless, the study argues, the profitable way to expand the supply of phenylalanine is through the synthetic route.

As of now, there is no commercial synthetic phenylalanine process. According to the Eldib study, Japanese, U.S., and European petrochemical producers currently are developing such processes.

The market for aspartame, the key to phenylalanine's future, will grow steadily around the world, the report says, as governments approve its use outside the U.S. Searle, which had global aspartame sales of about $14 million in 1981 and between $40 million and $50 million last year, expects to sell $500 million worth of the sweetener in 1986. To do so, two major hurdles will have to be overcome: one, Food & Drug Administration approval for the use of aspartame in soft drinks in the U.S.; and, two, a lower price for aspartame, currently far more expensive than saccharin.

It took Searle well over a decade to get FDA to approve aspartame for tabletop sweetening and for use in powdered drink mixes, dry cereals, puddings, gelatins, whipped toppings, and chewing gum. The next step—approval for use in soft drinks—will not take as long, the company confidently predicts. Searle anticipates the go-ahead sometime this year. The step is crucial, because, for the most part, aspartame's growth must come at the expense of saccharin, and 70% of saccharin's sales of $3 billion per year are in the soft drink sector.

Once approved, aspartame will have to battle doubts about its stability and shelf life, but the artificial sweetener's success in soft drinks in Canada, where both saccharin and cyclamates are banned, likely will help overcome them.

Less easy to overcome, however, could be the price differential between aspartame and saccharin. On a sweetening equivalency basis, aspartame is 20 to 30 times more expensive than saccharin. One development that would help: A process to make L-phenylalanine that could be sold for less than its current global price of $23 to $27 per lb.

Eldib's glowing forecast assumes both developments—FDA approval later this year and new, cheaper processes for both phenylalanine and aspartic acid, the other important amino acid ingredient in aspartame.

L-Phenylalanine supply is not overabundant even now, however, and it is possible there will be shortages as the aspartame market expands. "I'm not worried about the amino acid supply now," comments Eldib, "but we will have to at some point. Someone has to commit himself to producing it by a different process." □

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Natural gas-based petrochemicals

Methanol the best of bad lot

A Key Chemicals Review Page 23

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Cover: Getty Oil's $110 million, 100 million gal-per-year methanol plant at Delaware City, Del., due for completion in first-quarter 1983

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CHEMICAL & ENGINEERING
NEWS
JANUARY 24, 1983

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■ **Researchers successfully transfer functioning genes from bacteria into plant cells.** Page 6

■ **Report finds that federal support for R&D in fiscal 1983 has increased slightly from fiscal 1982.** Page 7

■ **Study chastises federal agencies for making regulations without reviewing scientific evidence.** Page 7

■ **White House prediction of low GNP growth in 1983 said to have disturbing implications.** Page 8

■ **EPA denounces Congressional report faulting agency's hazardous waste enforcement program.** Page 8

Business

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Three artificial sweeteners—aspartame, acesulfame-K, thaumatin—are getting close look in Europe. **Page 29**

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Nations will be allowed to set their own rules for approving new chemicals entering the marketplace. **Page 35**

Science

Lederle's new toxicology laboratory is especially designed for efficient research and computerized data gathering. **Page 41**

Education

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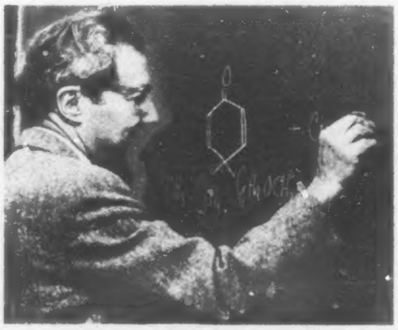


News Focus

Harvard's Frank H. Westheimer reflects on his 1965 report and details views on the current state of chemistry. Page 14

Outlook Mixed for Natural Gas-Based Petrochemicals

Methanol will be helped by fuel uses, formaldehyde by housing recovery; but ammonia and urea will be hurt by agricultural woes

Bruce F. Greek, C&EN Houston

Basic U.S. chemicals produced starting with reforming natural gas are developing divergent fortunes as 1983 opens. Prospects are that this new divergence could continue throughout much of this decade. Those containing nitrogen—ammonia and urea—could face lower production for some time. By contrast, the outlook for the other two—methanol and formaldehyde—may brighten as a result of new demand.

But all of these small-molecule petrochemicals face major problems in competition from foreign sources. They are headed for the same combination of increased imports and decreased exports expected for many other large-volume U.S. chemicals.

Because of the decline in farming income in most parts of the world, ammonia and urea demand decreased radically in both U.S. and foreign markets for U.S. producers during 1982. The decline appears to be carrying over into 1983, but at a slower rate. A turnaround in demand might occur in 1984, but the variables of weather, politics, and economics make long-term forecasts risky.

Production of methanol and formaldehyde also declined quite rapidly during 1982. Fortunately, the new fuel uses of methanol are growing—admittedly at least a year later than by most forecasts—and are expected to give a good boost to 1983 demand. Later on, fuels will continue to be a fast-growing use of methanol. U.S. production to meet demand in fuel use might be tempered, however, by a rising tide of imported methanol from countries such as Canada and Saudi Arabia with lower-cost natural gas.

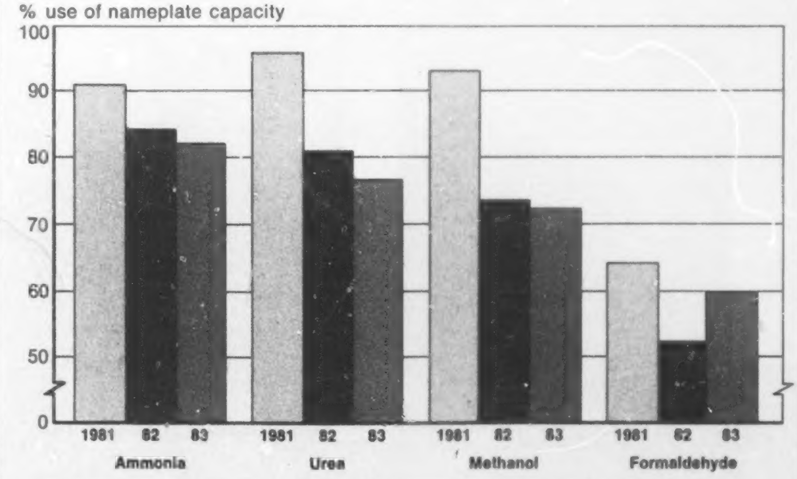
The impact on these four major C_1-petrochemicals from the 1982 slump was in line with the general drop in output of chemical commodities. Production declines ranged from 13 to 17%. Prices fell sharply, too, and production value nose dived.

Combined production volume dropped 15% in 1982 to 57.7 billion lb for the four chemicals (including the water content of formaldehyde solutions). Another slight combined drop looks likely for 1983, bringing the total optimistically to just under 57 billion lb.

The substantial drop in production value for these petrochemicals may not yet be quite over. Current industry estimates of production value for these four products for 1982 now total $4.2 billion, off 16% from 1981. Another $200 million could come off in 1983 unless prices and demand exceed present expectations. Hence, the net drop in value for 1983 will be about 20% from 1981, unadjusted for inflation. Ammonia and urea will account for 90% of this decline.

Key Chemicals

Although prospects for production increase beyond 1983 might be fairly good, prospects for price increases are dimmed by potential import competition. Currently, industry complaints about low-cost ammonia coming in from Mexico are being considered by the Commerce Department. Many in the ammonia industry believe that resolution of these complaints, even if favorable to U.S. ammonia producers, may come so late this spring that U.S. plants



Capacity use this year will stay low

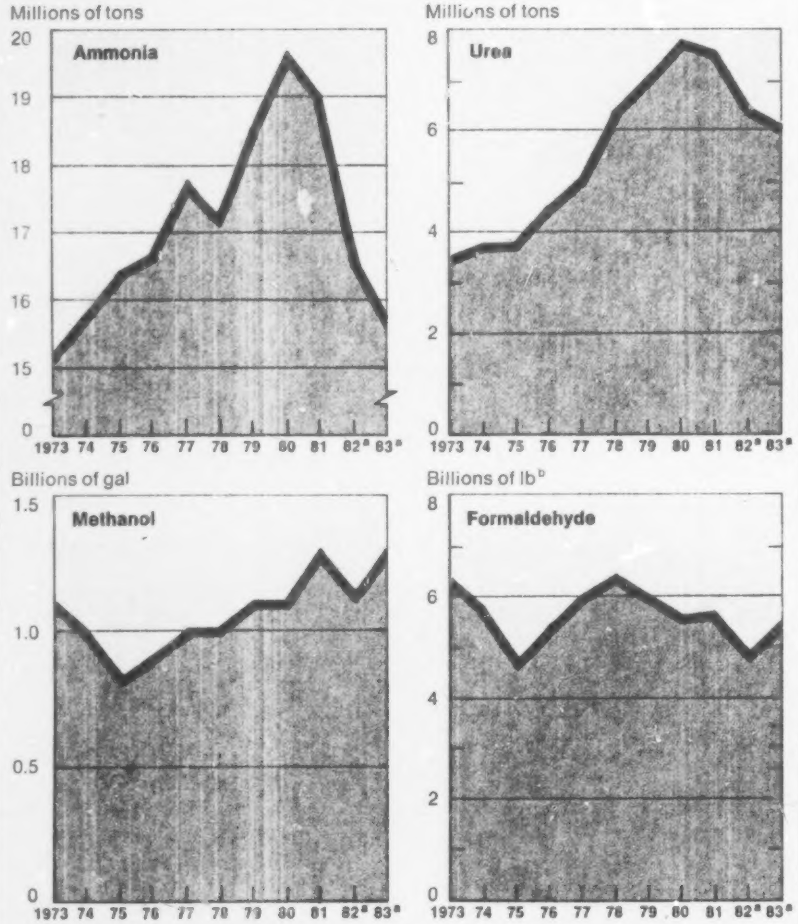
Sources: Industry, C&EN estimates; Department of Commerce, International Trade Commission now shut down won't be restarted in time to sell much production during the big spring market surge.

For the longer term, continued low-priced imports of ammonia and loss of export markets for ammonia, urea, and other ammonia derivatives likely will bring more decline in U.S. ammonia production. The exception would be if U.S. farmers increased application rates for fertilizers and planted larger acreage. But neither of these possibilities seems likely to help U.S. ammonia producers for the rest of the 1980s.

One result is growing concern by various analysts of ammonia and the agricultural industry about U.S. dependence on foreign sources of fertilizer nitrogen. One alarmist viewpoint holds that a temporary shortage of ammonia at the planting season could take away a large part of a year's crop.

Similarly, longer-term imports of methanol could hurt expansion of U.S. methanol capacity. Although at the moment a big addition to U.S. capacity is being completed, little more seems likely until much later in this decade.

Much of this U.S. capacity expansion in methanol is aimed at the automotive fuels market. Industry analysts expect gasoline to continue to be a growing blending market for methanol itself and for methanol derivatives such as methyl *tert*-butyl ether (MTBE). These uses aim at gaining the octane value of methanol for upgrading the octane value of unleaded gasoline.



1982 recession hurt production of all four petrochemicals

a Estimate b As a 37% solution. **Sources:** Industry and C&EN estimates; Department of Commerce, International Trade Commission

There is controversy, however, on the subject of methanol and derivatives in gasoline. On the one hand, increased octane value is a plus. For some time these materials have been a less-expensive way to gain octane than by using additional quantities of competing aromatics such as toluene.

On the other hand, possible disadvantages with methanol and derivatives start with corrosive effects on auto fuel systems and gasoline handling systems. Add to this the lower heat value of methanol compared to gasoline. In addition, some drivability problems have cropped up because gasoline-methanol blends have unusual changes in vapor pressure.

Disagreement over these factors leads to divergent views on the volume of methanol that will go into fuels over the longer term. Few analysts doubt a surge in fuel use of methanol or derivatives in 1983 from a small base. The pickup might continue at lower rates for several years until surplus U.S. methanol capacity and low-cost import volumes are used up. By then, some analysts speculate that fuels uses easily could exceed formaldehyde as the largest single methanol market.

At this point, even if for some reason use of methanol and derivatives in gasoline should slump, optimists forecast that methanol could be used in power plants—especially imported methanol made as an alternative way of shipping natural gas and as a way of gaining hard currencies. In power generation, methanol would have special advantages such as no sulfur combustion products and adaptability to peak shaving needs.

Pessimists, by contrast, claim that corrosion, handling, and auto drivability problems may make methanol fall out of favor in fuels as quickly as it came in. Unknowns yet to be explored are longer-term effects of methanol on the reinforced plastic tanks gaining use for storage at gasoline outlets. There also is the question of leaks. These concerns may delay government waivers on greater use of methanol in gasoline.

For the near-term outlook for these four C_1-petrochemicals, please see the following pages.

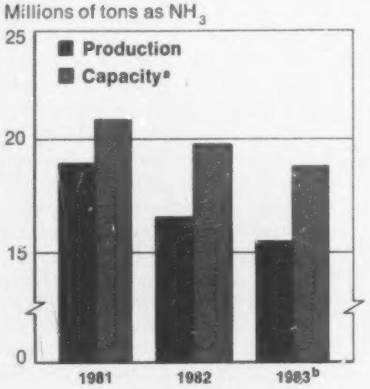
Key Chemicals

NH_3

Ammonia

- ***Production falling***
- ***Some capacity closing***
- ***Prices low, holding***

PRODUCTION/CAPACITY



a First quarter. b Capacity includes more than 4 million tons shut down, some of it permanently.

HOW MADE

Catalytic reaction of nitrogen from air and hydrogen from natural gas

MAJOR DERIVATIVES (U.S.)

Nitric acid 20%, urea 20%, ammonium phosphate 15%

MAJOR END USES (U.S.)

Fertilizer 80%, fibers and plastics 10%, explosives 5%

FOREIGN TRADE

Exports—might reach 1 million tons in 1983, imports—could rise to nearly 2.5 million tons in 1983

PRICES

$115 to $125 a ton on Gulf Coast

COMMERCIAL VALUE

$2 billion for production, 1983

U.S. ammonia producers continue to be burdened by a multitude of problems. They face higher raw material natural gas costs, other production and transportation cost increases, growing competition from lower-cost ammonia from foreign countries, loss of some of their final customers, and decreasing ability of most of their remaining customers to buy as much fertilizer as in the past.

So producers still are doing what they have done over the past few years—shutting down plants. In general, producers who continue to operate sell on a "cash-cost" basis, by which price covers only producers' direct cash operating costs. Most producers apparently have a negative cash flow.

In the current crop year ending June 30, farm commodity prices have continued their drop in real value with a possible slight acceleration. Prospects for increased commodity prices wax and wane with government proposals to help farmers. For ammonia, and fertilizers generally, these commodity prices largely will tell the near-term prospects for production and sales.

This means that, for calendar year 1983, production forecasts for ammonia are not bright. Predictions range from 15 million to 16 million tons of ammonia, down perhaps 1 million from an estimated 16.5 million tons for 1982. This decline will follow an even larger decline of 1.5 million tons in 1982 from just over 19 million tons in 1981.

Beset by greater costs and competition from imports, ammonia producers have been shutting down plants at about the same pace as the output decline. Because of these shutdowns, estimates of nameplate capacity for ammonia are called suspect by more and more industry analysts. Actual scrappage announcements seem to be coming faster now, suggesting that more and more producers will strike shutdown ammonia capacity from the list of potential restarts.

About 1 million tons per year of ammonia capacity has been scrapped or permanently shut down during the past two years. Currently, more than 4 million tons of capacity is shut down. Some industry sources believe that half of this capacity will not be restarted. Most sources expect that at least 1 million more tons of capacity will be taken permanently from the list in 1983.

With this pace of shutdowns following production cuts, nameplate capacity use remains relatively high for ammonia compared to many other large-volume chemicals. This has been the case for a long time. It is a characteristic of the industry and an important clue to how producers manage costs.

Even now, capacity in operation is far below the most pessimistic forecasts for 1983 production of ammonia. Nameplate capacity of ammonia plants operating in early January totals about 14.75 million tons per year. Few expect 1983 production to be less than 15 million tons. Clearly, some capacity will have to restart soon. And a possibility exists of spot shortages this spring during planting season.

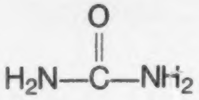
Any shortages could help ammonia producers by pushing up prices during the high-demand season. Price could increase 30 to 50% some time this spring from the present range of $115 to $125 per ton. The increases might last longer, if foreign sources prove more unreliable than they already have been.

However, higher prices naturally would spur foreign producers to get plants back on stream as quickly as possible or to ship from inventory previously reserved for internal use. After the end of the high U.S. demand season and a rush of imports, higher U.S. ammonia prices might not last long enough to help U.S. producer finances significantly in 1983. In this event, shutdowns simply would continue.

Because most ammonia is made into derivatives, and large amounts of these derivatives—particularly ammonium phosphates and urea—are exported, the actual end-use breakdowns become blurred. Another complicating factor is that considerable ammonia is imported and converted to derivatives. Derivatives with agriculturally useful nitrogen are then re-exported. Until 1981, the U.S. had had a net nitrogen export balance for several years. A flip-flop since then has made the U.S. an unwilling net importer.

Overall, unless unexpected changes occur in farm prices and exports in 1983, the year will go down as one of the worst for ammonia in many years.

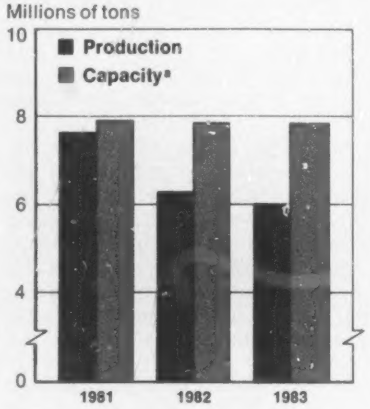
Key Chemicals


$$H_2N\text{—}\overset{\overset{\displaystyle O}{\|}}{C}\text{—}NH_2$$

Urea

- ***Production falling***
- ***Capacity down***
- ***Prices weak***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Reaction of ammonia and carbon dioxide under pressure

MAJOR DERIVATIVES (U.S.)

Urea-formaldehyde resins 5%

MAJOR END USES (U.S.)

Fertilizer 80%, adhesives and plastics 10%, animal feed 5%

FOREIGN TRADE

Exports—declining to about 1.25 million tons in 1983, imports—holding at about 1 million tons in 1983

PRICES

$120 to $125 a ton on Gulf Coast

COMMERICAL VALUE

$800 million for production, 1983

Urea and ammonia frequently come from the same producer, and the two products share similar problems. Whereas fertilizer is the dominant use of urea, ammonia's ills in the fertilizer industry also are those of urea.

Production of urea continues to fall, and a number of plants are now shut down. Because of the many nonproduction influences on urea demand, such as weather and exports, estimates of production early in any year range widely. For 1983 the spread of estimates is wider than usual; they center on 1983 production of 6 million tons. The range, however, goes from less than 5 million tons all the way to 7 million tons.

More than in almost any other large-volume chemical, pessimists and optimists' views clash for urea. Part of the problem comes from difficulties in getting good overall statistics. For example, industrial uses of urea often are ignored by agricultural analysts. Export data come in slowly, too. U.S. government production data are considered relatively imprecise, generally too high.

Less murky are the underlying reasons for a weak year for urea. They are mostly those common to the whole fertilizer industry. Farm commodity prices, farmers' debt levels, and related woes will influence urea demand this year very unfavorably. Exports are expected down too, because of the same factors in other countries plus increasing competition in export markets from urea produced in other countries, especially Eastern Europe.

These negatives help set up the more sour view for urea this year. According to the pessimists, even with sizable reductions in U.S. urea inventories this past fall, production this spring will go only to meet immediate demand, even at the risk of spot shortages and possible lost sales. Demand this spring then will provide producers a pattern for production next fall. If spring demand is weak and suggests little need to build inventories in the fall, 1983 production could come in at a mere 5 million tons.

Optimists demur. They say that good weather, better farm commodity prices as a result of acreage set-asides, and export demand improvement will combine to make a better year for urea in 1983 than in 1982. Their forecast production level of 6.5 million to 7 million tons of urea in 1983 will be up as much as 11% from an estimated 6.3 million tons in 1982.

Plant capacity for urea apparently has undergone no scrappage. This is not to say that large amounts of the capacity remain idle. As the year turned, at least as high a fraction of urea capacity was shut down as in ammonia, more than 20%.

Urea producers differ a bit from ammonia producers in that if they have a raw material carbon dioxide supply, they can continue to operate by purchasing ammonia. Some are believed to be doing this now because of the low ammonia prices. This opportunity could account for producers hanging on to their shut-down plants rather than scrapping them.

Hence, given urea's large shut-down capacity and questions about how much of it will run again, the estimated operating rate for nameplant capacity can cover a wide range. For 1983, the rate could range from 65 to 90%. A middle estimate would be 77%, below the level of ammonia plants.

Similar to ammonia, no significant new capacity for urea will be coming in the U.S. for some time. Prices, now about $120 per ton on the Gulf Coast, could be giving a negative cash flow to producers that are still running, unless their ammonia costs are very low.

As is the case with ammonia, imports of urea are rising from nothing in past years to substantial quantities from countries such as East Germany and Qatar. These imports aim to take advantage of factors such as the strong dollar.

The nonagricultural uses of urea are not helping overall production either. Resins outlets, urea-formaldehyde and melamine, have been hit by the housing slump. Even a sharp recovery in housing this year will not be enough to do very much for urea as a whole because these resins account for less than 10% of U.S. urea use.

Hence for 1983, urea will ride uncomfortably with fertilizers' fortunes in both the U.S. and abroad. Although many variables could change demand from forecasts, hope for a better year than 1982 at the moment seems quite dim.

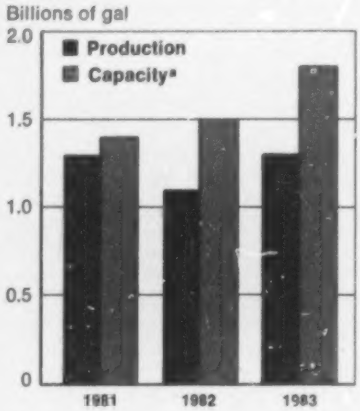
Key Chemicals

Methanol

CH_3OH

- ***Demand to rise***
- ***Capacity way up***
- ***Prices discounted***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Reaction of carbon monoxide with hydrogen made by reforming natural gas or heavier hydrocarbon fractions

MAJOR DERIVATIVES (U.S.)

Formaldehyde 30%, acetic acid 10%

MAJOR END USES (U.S.)

Polymers uses as adhesives, fibers, and plastics 50%, solvents 10%

FOREIGN TRADE

Exports—holding at about 100 million gal in 1983, imports—rising to about 100 million gal in 1983

PRICES

List prices 72 cents a gal and higher; discounting significant

COMMERCIAL VALUE

$750 million for production, 1983

Methanol has become one of the few major-volume U.S. chemicals with a new, fast-growing use—fuels. This outlet, considered by most in the business as nonchemical, probably will help spur production in 1983 to at least the level of 1981, or some 1.3 billion gal. It also is sparking a part of the major U.S. methanol capacity either just started up or expected on stream later this quarter.

Such a production increase of more than 15% in 1983 for methanol will come from several pressures. Obviously, one is to build an operating inventory for producers who are adding capacity. Another, the largest, will be the growing fuel market, which easily could take more than 100 million gal in 1983, accounting for about half of the overall expected production growth. Old-line uses such as making formaldehyde also are expected to recover as some improvement takes place in housing and other construction. And a newer use, making acetic acid, also is expected to add to demand in 1983.

The possibilities are strong, according to some industry hopefuls, for an even better 1983 than this for methanol. These optimists say that production could top 1.4 billion gal, because fuels' uses of methanol could reach 150 million to 200 million gal. Other methanol uses, they say, are about the same as in more conservative forecasts.

There are several fuel uses of methanol. For some time now, the gasoline additive methyl *tert*-butyl ether (MTBE), the product of a reaction of methanol and isobutylene, has required significant quantities of methanol as its use grows as an octane booster for unleaded gasoline. More recently, a blend of methanol and *tert*-butyl alcohol, sold by Atlantic Richfield as Oxinol, has been added to gasoline, also as an octane-value additive. In the future, straight (neat) methanol might be added to gasoline if the Environmental Protection Agency approves a petition by Du Pont to allow methanol to be blended into unleaded gasoline in quantities up to 3%.

Currently, only 0.3% methanol can be added to gasoline. This small amount has been allowed to take up any water in gasoline to reduce icing problems in cold weather.

If methanol were added to gasoline above 3%, or possibly 5%, enough water pickup would occur to cause a phasing out of a methanol-water layer, according to industry sources. When such a separation does occur, corrosion problems develop fast. To overcome this problem, a low-cost and effective cosolvent—*tert*-butyl alcohol, for example—is used.

The long-term fuel potential for methanol looms far beyond current plant capacity. If U.S. annual gasoline consumption is 80 billion gal, and half of that is unleaded (both conservative estimates), and 1% methanol is added in one form or another, this annual methanol use would total 400 million gal. At 4%, the fuel demand could exceed present U.S. nameplate capacity to make methanol.

Some U.S. refineries of crude oil apparently have made this connection, because they account for most of the methanol capacity expansion coming on stream now. Arco Chemical has just started up its new unit at Channelview, Tex., adding 200 million gal per year of capacity, and Getty Refining shortly will add 100 million gal of capacity at Delaware City, Del.

These expansions and other smaller capacity additions from 1982 will bring U.S. nameplate capacity for methanol to 1.8 billion gal for most of 1983. If production of methanol reaches 1.3 billion gal, plants will need an average operating rate of about 73%. If the more hopeful industry analysts prove right, the rate could reach 76%.

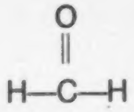
Next to fuel, the fastest growing use of methanol is in making acetic acid. Here, methanol is in effect a replacement for ethylene. Although rapid growth slows as the base gets larger, this year acetic acid manufacture likely will take about 10% of methanol production.

Formaldehyde will hold first place as a use of methanol for some time to come. It was hit hard in 1982 because of the decline in demand for adhesives in making plywood and in making polymers for components for cars and appliances. In 1983, demand for formaldehyde could recover almost to 1981 levels, pulling methanol along.

So 1983 will be a better year for methanol. Fuel uses may grow enough to hold up plant operating rates even as capacity expands some 20%.

Key Chemicals

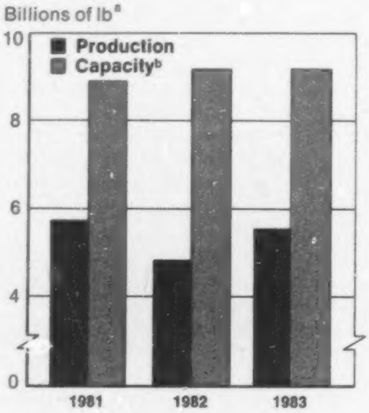
Formaldehyde



$$H-\overset{\overset{\displaystyle O}{\|}}{C}-H$$

- ***Demand to pick up***
- ***Capacity flat***
- ***Prices weak***

PRODUCTION/CAPACITY



[a] As a 37% solution. [b] First quarter.

HOW MADE

Catalytic oxidation of methanol

MAJOR DERIVATIVES

Urea-formaldehyde resins 30%, phenol-formaldehyde resins 20%

MAJOR END USES

Adhesives 60%, plastics 15%

FOREIGN TRADE

Exports—small, possibly 25 million lb in 1983, imports—negligible

PRICES

List prices—about 9 cents per lb for 37% solution; merchant volume small, with prices discounted

COMMERICAL VALUE

$500 million for production, 1983

Formaldehyde continues to struggle with bad fortune made up of two parts. The concern over carcinogenesis hasn't been laid to rest, even though some studies indicate no notable effect on workers and even though the government banned urea-formaldehyde foam insulation in homes and schools. Add to this the shock of the 1982 recession in housing, which probably dropped formaldehyde production 16% in 1982.

Seasonality of demand for formaldehyde makes estimates of 1982 production somewhat uncertain, but output probably totaled 4.8 billion lb of 37% solution. This was down at least 1 billion lb from initial estimates for the year, which assumed a good fourth quarter in housing. If the more dour industry opinion proves accurate for the fourth quarter, 1982 production might have been off even more, possibly 4.6 billion to 4.7 billion lb.

Despite its current pickup, the housing industry doesn't inspire all formaldehyde industry sources for 1983. Some say that the pickup in housing and commercial construction is still weak and will not be much better later on this year. Hence, the middle estimate of 5.5 billion lb of 37% solution formaldehyde production for 1983 could be high by 5%, according to the pessimists.

But other analysts see a better year. They say that 1983 production will match 1981 at about 5.7 billion lb. The optimists lay the roughly 1-billion-lb production increase in 1983, or 20% precisely, to an anticipated surge in housing starts. One part of this will be a unit volume increase, which will carry along with it increased demand for plywood and particle board using formaldehyde-based adhesives. Another part will be the need for more inventories of these adhesive materials following an upswing in demand. And a third part could be a shift to relatively more use of plywood and particle board as a cost-saving effort to further spur housing.

Whatever the final outcome in 1983 for formaldehyde, an increase in production would push producers' plant operating rates to between 58 and 62% of nameplate capacity. Although not as good as rates for many other major-volume organic chemicals, these percentages will be well above the 1982 range of 50 to 52%. Clearly, during 1982, many formaldehyde plants have been shut down for varying periods of time. Such plants are closely tied to plants making resins for plywood and particle board. Many of these formaldehyde plants are relatively small, and a shutdown and startup costs little.

Which plants are shut down and kept down may hinge on the outcome of efforts to set standards for formaldehyde emissions. For 1983, most industry sources expect little impact if standards are finally set—probably late in the year if at all. In any case, after 1983, standards and concern over emissions could have a big impact on the plywood-particle board use of formaldehyde, which accounts for half of all formaldehyde production.

Besides resins used mainly as adhesives, formaldehyde goes into many other derivatives, many of which also are resins. None of these other uses is nearly as large as the urea- and phenol-formaldehyde resins. None except for some very small volume specialties is expected to grow at rates much above those of the adhesive resins.

Polyacetal resins, for example, are expected to aid recovery of formaldehyde production during 1983 because these resins go into various small parts. They are among the faster growing uses of formaldehyde over the long term.

Butanediol competes with the polyacetal resins as a more rapidly growing use of formaldehyde. This specialty intermediate goes into a variety of uses such as thermoplastic polyester, polyurethanes, and solvents. One of the bigger uses also hit by the housing decline is manufacture of tetrahydrofuran, a solvent for the cements used in joining polyvinyl chloride pipe.

Somewhere between 15 and 20% of formaldehyde is consumed by miscellaneous uses—the third largest category after urea- and phenol-formaldehyde resins. Although some of these are sizable—but not 5% of the total—none has volume or growth rates large enough to change formaldehyde's outlook for several years.

For 1983 then, formaldehyde's fortunes remain tied to its big uses. A good recovery in housing, if not a boom, could bring formaldehyde production back to about 1981 levels.

JANUARY 31, 1983

CHEMICAL & ENGINEERING NEWS

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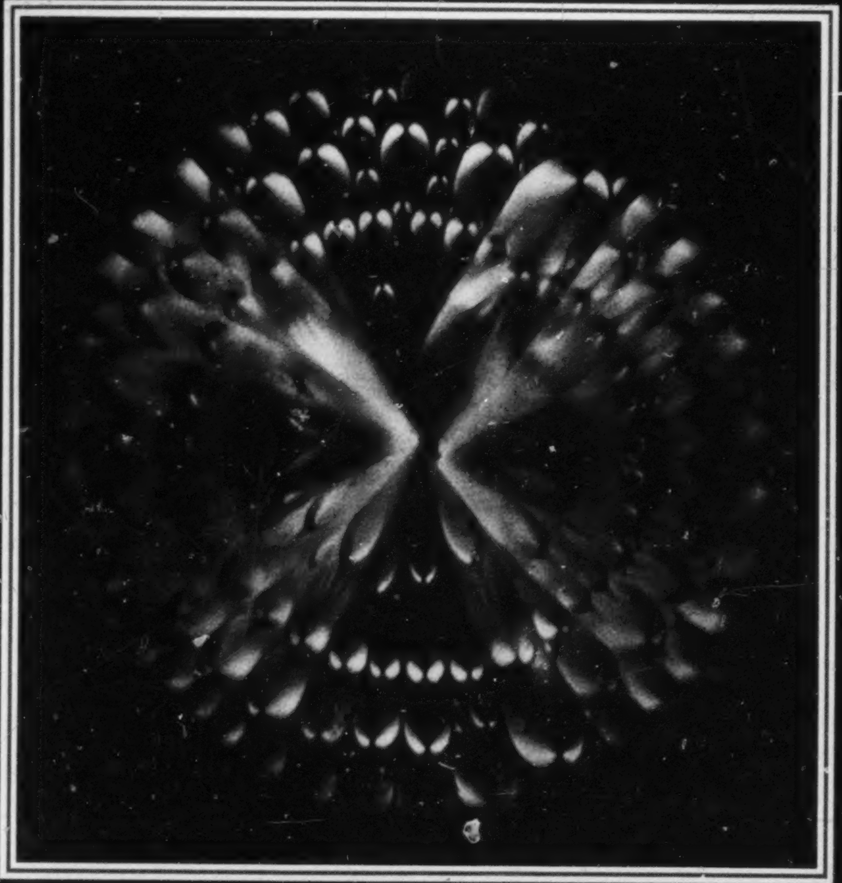

liquid crystals

A colorful state of matter

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Cover: Focal conic texture of a smectic A liquid crystal, as seen in a photomicrograph by Alfred Saupe, Liquid Crystal Institute

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CHEMICAL & ENGINEERING NEWS

JANUARY 31, 1983

News of the Week

- **U.S. chemical companies finish 1982 in a slump, hope the coming year will be better.** **Page 4**
- **Detection of the subatomic W particle causes a stir in the physics community.** **Page 5**
- **Basic petrochemicals producers are confident they can withstand lower OPEC prices.** **Page 5**
- **Long-range projections by NSF show national R&D spending at $45 billion level by 1990.** **Page 6**
- **International studies tend to support the alleged use of chemical arms in Southeast Asia.** **Page 6**

Business

Air Products & Chemicals looks to shift in markets to help reverse recession losses; high-technology markets favored. **Page 8**

International

Japan's petrochemical industry seeks solutions to its ills, focuses on restructuring to cut excess capacity. **Page 11**

Government

Polymetallic sulfide deposits found in both Atlantic and Pacific oceans contain some strategically important materials, pose problems for government regulation. **Page 14**

Science

Electron density mapping is being applied to molecules containing heavy elements, and is providing reliable information. **Page 17**

Biotechnology seen as helpful for solving agriculture, health, and energy problems in developing nations. **Page 19**

Research in physical chemistry gets a boost from more advanced techniques in spectroscopy, magnetic resonance. **Page 20**

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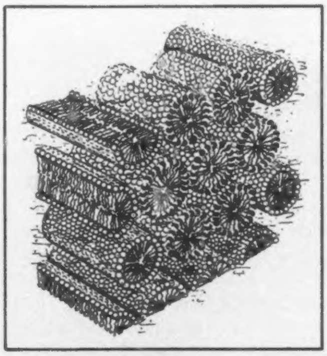

Special Report

Liquid crystals occupy a grey area between true solids and true liquids, but have unique properties of their own. **Page 24**

er major benzene source, is down to about 30%.

As a result, the spot price of benzene, for several months well below the listed price, has now moved up to the same level as the effective contract price of $1.45 per gal. In normal times, that would mean the contract price was poised to rise again.

Analysts say that even a $4.00 reduction of the benchmark crude oil price would not affect aromatics pricing. Refinery output is expected to remain low, because most analysts do not believe even cheaper gasoline or heating oil would stimulate consumer demand enough for several months to raise capacity utilization. That will keep aromatics production low. "No one is going to crank up a refinery to make aromatics," one observer remarks.

Producers' confidence wanes at the mention of an oil price collapse. In that case, they say, aromatics prices would react within a few weeks to customer pressure for lower prices. But few producers or analysts expect a much lower petroleum price. Political and commercial expediency, they predict, will get the OPEC members to patch up their differences before that happens. ☐

NSF projects 1990 R&D spending of $45 billion

In 1990, national R&D expenditures will reach between $43.5 billion and $46.7 billion, in 1972 dollars. These figures are based on average annual increases of 2.5 to 3% over 1979 expenditures of $33.8 billion, compared to an average annual increase of 4.5% between 1975 and 1979.

That's the R&D outlook projected by the National Science Foundation in a current analysis of R&D funding trends. NSF made its first attempt at long-range projections of national R&D spending in 1976, looking toward such expenditures in 1985. The current analysis employs the same techniques, with a major exception being that of industry funds. The current projection makes use of an R&D cost per employee ratio and applies it to projected employment data, whereas in 1976 the analysis used an R&D-to-sales ratio and applied it to projected sales.

In a breakdown of 1990 R&D spending, the federal government is projected to increase its R&D spending by an average of about 2% per year in constant dollars between 1979 and 1990. Defense, now about half the federal R&D total, is projected to grow sharply during the early 1980s and to slow slightly thereafter. Industry's share of federal R&D dollars would increase from 45% in 1979 to more than 50% in 1990, because nearly two thirds of defense R&D is contracted to industry.

Universities and colleges and other nonprofit institutions are projected to increase their R&D spending from all sources by an average of 2% per year in real terms between 1979 and 1990, about half the rate between 1975 and 1979. Reflecting increased defense spending, federal R&D support of these institutions is expected to increase only 1% per year to 1990, a decline in growth from 3% annually over earlier periods. Nonfederal support is projected to continue at about the same 3% rate.

NSF expects industrial R&D spending to increase at average annual constant-dollar rates of 3 to 4% between 1979 and 1990. It expects growth to be greatest in computer- and instrument-related industries, about 50% higher than the all-industry average. The analysis projects industrial spending on chemical R&D, including drugs, to reach between $2.97 billion and $3.16 billion in 1990 (in 1972 dollars), up from $2.26 billion in 1979. ☐

Industry will lead the way in 1990 R&D funding

$ Millions, 1972	1979	1990 High	1990 Low
Federal government	$16,545	$20,425	$19,775
Industry	15,990	24,424	21,988
Universities and colleges	733	1,050	1,000
Other nonprofit institutions	514	775	725
TOTAL	$33,782	$46,674	$43,488

French findings hint yellow rain toxin use

The French Ministry of External Relations says that international studies, with France's participation, tend to support allegations that chemical arms are being used in Southeast Asia. A spokesman for the ministry says the weapons are not of natural origin and are not indigenous to the region.

That statement follows reports from the French Embassy in Bangkok, Thailand, that France had collected specimens from the Thai-Kampuchean border, where Kampucheans are fighting Vietnamese forces, and had analyzed these samples in Paris. Several of the specimens have tested positive for the so-called yellow-rain toxins.

An unnamed French diplomat in Bangkok is reported to have said that some of the biological samples contained high concentrations of mycotoxins. A spokesman for the French Embassy in Washington, D.C., reading from an *Agence France Presse* dispatch, says that France will not reveal more information until there is "absolute and definitive evidence."

It is unclear whether France is awaiting rigorous confirmation of its own chemical analyses, or further proof of the U.S. allegation that the Soviet Union is supplying yellow-rain toxins to its Vietnamese allies.

The State Department would eagerly welcome the French findings. For the moment, State is trying to clarify whether the statements made are official French government announcements supporting U.S. allegations, or merely the pronouncements of individual French diplomats. Should the statements be deemed official, they will considerably bolster the credibility of U.S. allegations.

Several earlier Canadian studies have given only qualified support to the U.S. charges. U.K. tests of yellow-rain samples have been inconclusive. And the United Nations investigative team last December found "circumstantial" evidence of chemical warfare in Southeast Asia. ☐

FEBRUARY 7, 1983

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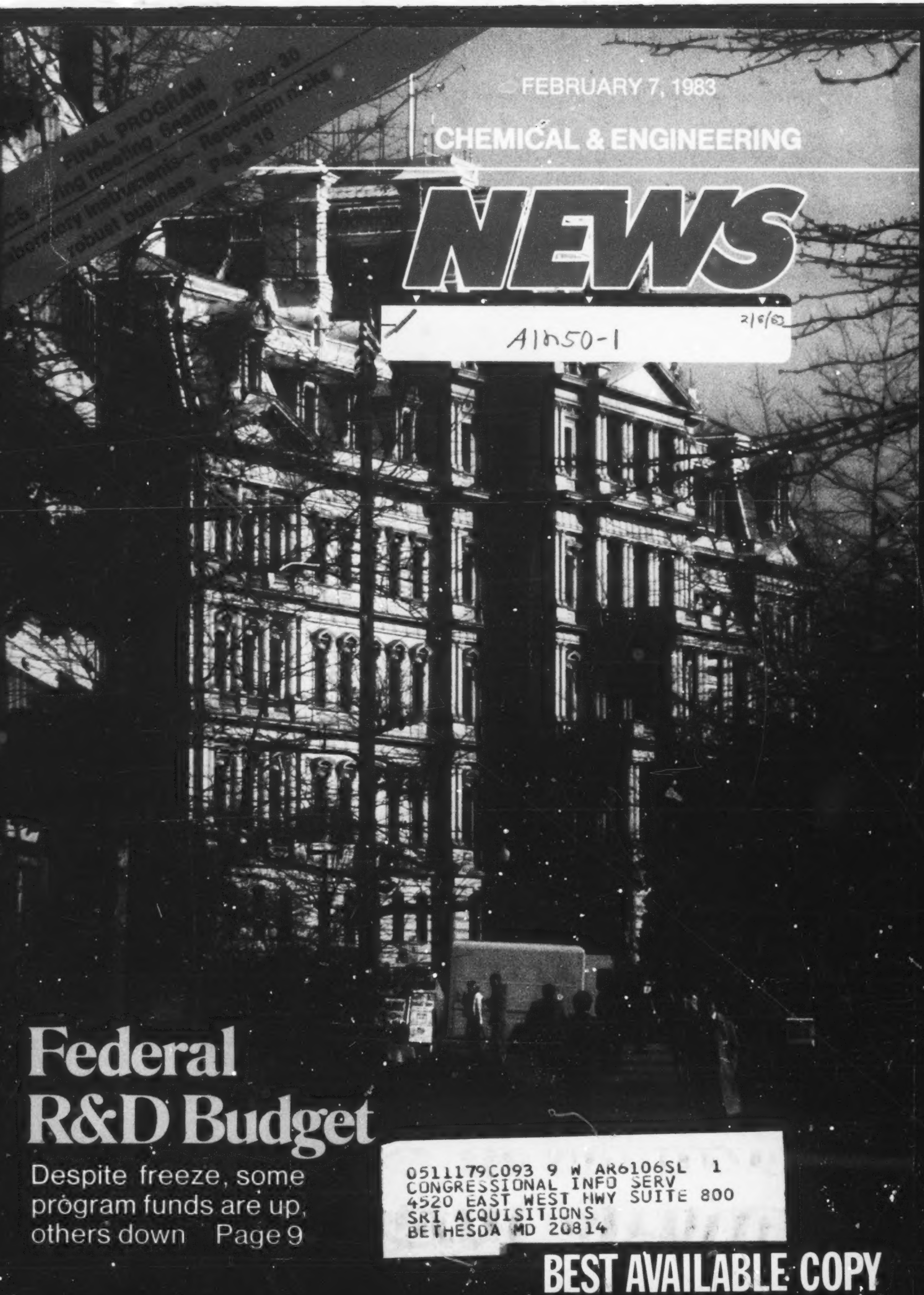

Federal R&D Budget

Despite freeze, some program funds are up, others down Page 9

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Cover: Old Executive Office Building, headquarters of the Office of Management & Budget. Photo by David J. Hanson

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CHEMICAL & ENGINEERING NEWS

February 7, 1983

News of the Week

- **1983 may be the year the U.S. chemical industry recovers from the recession, if the first two months are any indication.** **Page 6**
- **Details of the Administration's plan to upgrade science education include additional training for science and math teachers.** **Page 7**
- **EPA threatens to impose penalties on 31 states for not complying with air cleanup deadlines.** **Page 7**
- **Einsteinium's heat of vaporization and chemical valence are determined for the first time.** **Page 7**
- **Reusable ammonia detector has been developed that uses cheap, off-the-shelf components.** **Page 8**
- **Corporate R&D spending in the U.S. could be hurt if the moratorium on a vexing tax rule is allowed to expire this year.** **Page 8**

Business

Analytical instrument sales remain basically sound in spite of the recession, thanks to large U.S. and export markets. **Page 16**

Government

White House targets science and math education for improvement; proposed program would focus on grants to states. **Page 21**

Science

Tunable source of extreme vacuum ultraviolet radiation has been developed in which laser light is frequency doubled in a crystal, and then frequency tripled by pressurized gas. **Page 28**

Education

Manufacturers contribute to education almost four times as much money as do nonmanufacturers, survey finds. **Page 29**

Final Program

Program for the ACS national meeting in Seattle includes a complete guide to technical sessions, descriptions of tours, and listings of social and special events. **Page 30**

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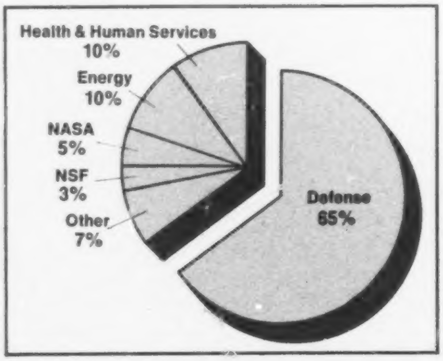
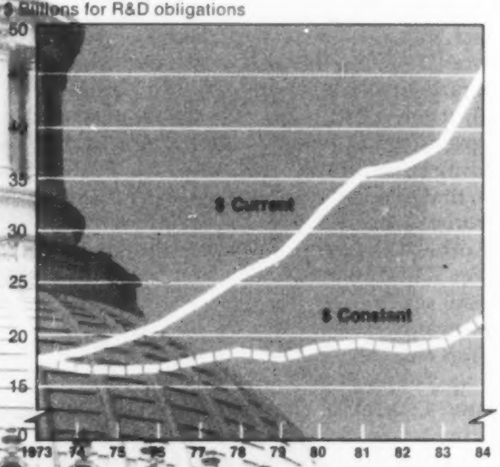


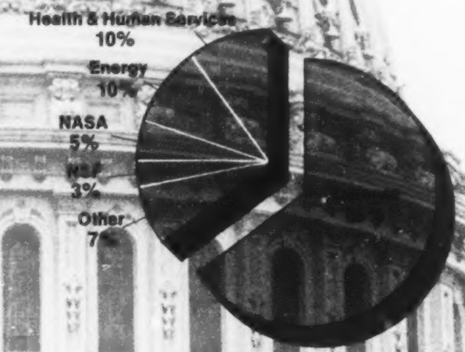
News Focus

1984 federal budget allocates a large share of the R&D pie to defense, but basic research also benefits. **Page 9**

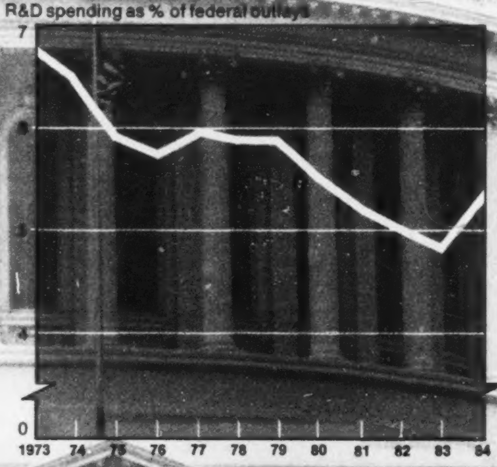
R&D funds to rise 12% in constant dollars



Department of Defense share of R&D budget jumps to 65%



R&D funding accounts for just over 5% of federal outlays



R & D would gain in 1984 federal budget

Almost all of proposed R&D funding increase is defense-related; basic research also would benefit

Janice R. Long and **David J. Hanson**, C&EN Washington

In the light of the overall freeze on domestic spending imposed by President Reagan, the research community may well be pleased with the fiscal 1984 budget proposal sent to Capitol Hill last Monday. In that budget, total obligations—money committed—for R&D would be up 18% to $45.8 billion, whereas outlays—money actually spent—would be up 12% to $42.7 billion. That would result in a two-year (1983–84) growth in federally supported R&D of 26% in obligations and 24% in outlays. The total federal budget, on the other hand, would be up only 5% to $848.5 billion. (Revenues are estimated at $659.7 billion, leaving a deficit of $188.8 billion.) Most of the increase in federal spending would be eaten up by a 10% increase in defense spending, leaving domestic programs level or down.

The budget also calls for a 10% increase to $6.6 billion in obligations for basic research, allowing a two-year growth of 22%. Outlays for basic research would be up 8% to $6.4 billion, for a two-year growth of 18%. Funding for R&D facilities, down 1% this fiscal year, would fall another 4.3% to $1.2 billion, and outlays, down 7.6%, this year would fall a further 4% to $1.1 billion.

Before the rejoicing becomes too widespread, a note of caution must be sounded—the increases in R&D obligations are far from uniform. Of the $6.9 billion increase in total R&D obligations, 96.6% would go to defense R&D. In fact, funding for seven of the 13 major federal supporters of R&D, as broken down by the Office of Management & Budget, would actually decrease in fiscal 1984; funding for the Department of Energy would be held essentially constant.

In basic research the increases have been targeted to the physical sciences and engineering, with funding in that area up 15% to $3.9 billion. Thus, funding for basic research would be up 18% at the National Science Foundation, 19% at the Department of Energy, and 13% at the National Aeronautics & Space Administration. In contract basic research, funding for the agencies that support primarily life and social sciences would be up

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Glossary of budget terms

Deferral. Any executive branch action or inaction that delays the availability of budget authority for obligations. Deferrals may not extend beyond the end of the fiscal year and may be overturned at any time by either branch of Congress.

Fiscal year. Year running from Oct. 1 to Sept. 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payments.

Outlays. Payments for obligations incurred under budget authority, generally made by issuance of checks by Treasury. Outlays during any fiscal year may be payments incurred in prior fiscal years or in the same fiscal year.

Rescission. Enacted legislation canceling budget authority previously granted by Congress. Rescissions proposed by the President must be approved by Congress within 45 days to become effective.

only 3% to $2.7 billion. For example, funding for basic research at the National Institutes of Health would be up less than 2% to $2.1 billion.

A breakdown of the federal R&D budget by agency shows the Department of Defense standing like a mountain in a field of molehills. It comprises 65% of the total R&D budget for fiscal 1984 and is more than six times larger than its nearest rival, Energy. The 1984 DOD figure of $29 billion represents a 30% increase above fiscal 1983, and a 46% rise from two years ago.

Significant increases have been proposed for all segments of DOD's research, development, testing, and evaluations programs. The largest, $3 billion, would be for strategic weapons projects, which include the Peacekeeper (many remember this as the MX) and Trident II missile systems. For tactical weapons, a $1.5 billion raise is proposed to support further work on the Army's M-1 tank, more reliable jet fighter engines for the Air Force, a new lightweight submarine torpedo for the Navy, and other projects.

Research performed in the technology base category, up 13% from fiscal 1983, would go toward developing very high speed integrated circuits for further miniaturization of microelectronic devices, plus research focusing on information processing, materials research, fault-resistant electronics, and advanced computer languages. Of the entire DOD research budget, just 3%, or about $870 million, is slated for basic research. This is a 13% increase above fiscal 1983.

When Congress gets around to looking for places to cut the budget—and it will—DOD's R&D program will be especially vulnerable. The huge sums requested for development and testing of the large missile systems were a sticking point in last year's budget debates and are sure to be again. Congressional leaders are seeking to cut Defense outlays as much as $30 billion next year to trim the mushrooming federal deficit, and the R&D area is a likely target.

If Congress also trims the Department of Energy's R&D budget request, it won't be because it's too fat. Overall, DOE's budget is slated for just a 6% increase in fiscal 1984 to $11.3 billion. However, its R&D budget would be down 4% to $4.3 billion and when one factors out the $195.3 million or 16% increase set for weapons R&D and testing, the outlook for the civilian R&D programs is bleak—they would be down 11% to $2.9 billion. In fact, things are so bad that the Energy Department is reduced to saying that although it can't continue to fund programs at the level approved by Congress for fiscal 1983, it has slowed the pace of its efforts to transfer programs to the private sector and is asking for more funding in fiscal 1984 than it did in fiscal 1983.

Be that as it may, under the budget proposal, funding for conservation R&D would be down 75%, that for solar and other renewable resources down 60%, and fossil energy R&D down 57%. On the bright side, funding for general science and research, which funds high-energy physics and nuclear physics, would be up 16% to $645.2 million and funding for supporting research and analysis up 24% to $408.5 million. (The rise could be even greater. Congress held a large part of DOE's fiscal 1983 funding to 1982 levels but implicitly gave it permission to move funds around within that total to reflect increases and cuts that the department had wanted to make. If held to 1982 levels in fiscal 1983, the requested increase for supporting research would be 52%.)

Funding for basic energy sciences would be up either 24% or 33% to $350.2 million, depending on which base level is used. Likewise, within that category, funding for chemical sciences would be up either 9% or 21% to $82.5 million.

New initiatives included in DOE's civilian R&D budget request include initiation of a national advanced materials research center at Lawrence Berkeley Laboratory, expansion of the National Synchrotron Light Source at Brookhaven National Laboratory, and a $6 million university instrumentation procurement program to provide large state-of-the-art equipment whose cost exceeds $100,000.

The Department of Health & Human Services may also have to do some belt tightening, though not to the extent that DOE will. The Administration has requested an increase of just 1.5% for fiscal 1984 R&D spending by HHS. This is the second year in a row that the proposed increase has been well below the rate of inflation. Of the nearly $4.2 billion proposed, the National Institutes of Health would get 90%, a slightly larger share than in previous years, indicating that other agencies that fund R&D, such as the Alcohol, Drug Abuse & Mental Health Administration, would get significantly less. Among the individual institutes, most would get a 1% or 2% increase, with the exception of the Environmental Health Services Institute, which is looking at a proposed 2% cut.

Specific research activities emphasized by the Administration for support next year include cancer chemoprevention, prevention of glaucoma, and biological responses to mixtures of drugs. Also mentioned prominently are clinical trials on a vaccine for herpes simplex viruses, on the effects of interferon on multiple sclerosis, on the role of folic acid in fetal neural tube defects, plus the ever-popular efforts to cure or prevent diabetes.

The total federal R&D package

Agency by agency R&D funding breaks down like this

$ Millions	Obligations			Outlays		
	1984[a]	1983[a]	1982[b]	1984[a]	1983[a]	1982[b]
Defense—military functions	$29,882	$23,179	$20,576	$26,844	$21,847	$18,201
Energy	4,713	4,712	4,758	4,911	5,012	4,974
HHS	4,416	4,316	3,935	4,339	4,262	3,978
NASA	2,473	2,506	3,084	2,421	2,386	3,220
NSF	1,240	1,060	975	1,137	1,002	1,014
USDA	849	850	798	848	839	808
Transportation	519	393	309	451	376	349
Interior	329	373	381	348	411	392
Commerce	227	312	290	249	315	285
EPA	208	241	335	250	295	336
Nuclear Regulatory Commission	200	210	221	200	210	209
Veterans Administration	163	165	140	156	157	138
Agency for International Development	161	152	165	152	200	179
Other	418	391	388	433	425	426
TOTAL	**$45,798**	**$38,860**	**$36,355**	**$42,739**	**$37,737**	**$34,509**

a Estimates. b Actual. **Source:** Office of Management & Budget

Funds for basic research would be up 10% to $6.6 billion

$ Millions	Obligations			Outlays		
	1984[a]	1983[a]	1982[b]	1984[a]	1983[a]	1982[b]
HHS	$2238	$2184	$1953	$2214	$2154	$1962
NSF	1181	998	916	1083	943	954
Energy	1021	861	777	1001	859	774
Defense—military functions	867	769	686	776	746	603
NASA	682	605	538	658	588	537
USDA	381	362	331	380	356	338
Interior	89	88	74	94	89	74
Smithsonian	68	60	55	62	60	47
EPA	17	21	33	22	25	30
Commerce	16	18	17	17	16	16
Veterans Administration	15	15	13	15	15	13
Education	14	16	16	18	22	22
Other	30	29	31	21	30	31
TOTAL	**$6619**	**$6026**	**$5440**	**$6361**	**$5903**	**$5401**

a Estimates. b Actual. **Source:** Office of Management & Budget

Funds for R&D facilities would be down 4% to $1.2 billion

$ Millions	Obligations			Outlays		
	1984[a]	1983[a]	1982[b]	1984[a]	1983[a]	1982[b]
Energy	$ 501	$ 619	$ 762	$ 532	$ 623	$ 804
Defense—military functions	438	323	290	349	289	232
NASA	156	160	92	129	136	109
HHS	29	60	29	35	31	38
USDA	26	38	30	22	45	30
Other	45	49	30	48	34	40
TOTAL	**$1195**	**$1249**	**$1233**	**$1115**	**$1158**	**$1253**

a Estimates. b Actual. **Source:** Office of Management & Budget

Among other HHS functions, the occupational health research done by the National Institute for Occupational Safety & Health remains at a steady level, although if the budget request is accepted it will not have received a funding increase in three years. The John C. Fogarty Center for advanced studies in health sciences and related international health activities, on the other hand, has been a consistent big winner with this Administration, with a 9.4% increase proposed for fiscal 1984, giving it an almost 60% rise since 1981.

The National Aeronautics & Space Administration, for years the second largest research and development agency (after Defense) in the federal government, has slipped this year to fourth. Although its total funding is still very high, its entire budget is no longer being labeled R&D. With the successful transfer of the space shuttle to the operational phase, funding for shuttle production, operation, tracking and data acquisition, and other support has been cut from the R&D figure.

Overall, the R&D budget proposed for NASA for 1984 is slightly lower than fiscal 1983, but the Administration wants some projects funded at a higher level than in this fiscal year. Funding for space transportation systems, which used to include most of the shuttle, would still be up and would be used to fund improvements in that vehicle and development of a new, high-energy upper stage for the Centaur rocket.

Space science programs, particularly physics and astronomy, would get the biggest boost for fiscal 1984. Items here include tracking of Voyager 2 as it continues on its way to Uranus for an encounter in 1986. Also funded in the budget are future launches for the space telescope, now planned for 1985, and the Gamma Ray Observatory for basic research in high-energy astrophysics.

Funds are also proposed to continue work on the Galileo mission to Jupiter. This two-stage spacecraft will include an orbiter as well as a probe that will enter Jupiter's upper atmosphere. It is expected to be launched in 1986 and arrive at Jupiter in 1988. A new program to radar map Venus is also proposed to start in fiscal 1984, as is a new Explorer-class program to

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How the agencies fare

NSF budget up 18% to $1.3 billion . . .

$ Millons	1984[a]	1983[a]	1982[b]
Mathematical and physical sciences	$ 364.3	$ 299.7	$272.8
Astronomical, atmospheric, earth, and ocean sciences	334.9	276.1	259.8
Biological, behavioral, and social sciences	223.6	190.2	176.6
Engineering	123.0	100.8	93.3
Antarctic program	102.1	83.2	68.5
Program development and management	66.0	65.3	63.2
Science and engineering education	39.0	30.0	20.9
Scientific, technological, and international affairs	36.8	44.2	40.3
Special foreign currency	2.6	3.1	3.6
TOTAL	**$1292.3**	**$1092.6**	**$999.0**

a Estimates. **b** Actual. **Note:** Obligations. **Source:** National Science Foundation

. . . with funding for chemistry up 21%

$ Millions	1984[a]	1983[a]	1982[b]	% change 1983–84
Physics	$107.6	$ 88.9	$ 75.3	21%
Physiology; cellular and molecular biology	102.7	85.5	80.1	20
Materials research	99.6	80.8	79.9	23
Atmospheric sciences	90.6	75.0	70.4	21
Ocean sciences	89.1	81.2	75.0	10
Chemistry	80.2	66.2	61.4	21
Astronomical sciences	79.3	63.0	59.1	26
Environmental biology	53.6	45.7	42.0	17
Mathematical sciences	42.2	34.7	30.5	22
Earth sciences	42.1	34.1	29.5	23
Behavioral, neural sciences	37.9	33.8	31.7	12
Computer research	34.7	29.1	25.7	19
Chemical and process engineering	27.1	22.3	20.4	21
Social, economic sciences	23.3	19.8	17.6	18
TOTAL	**$910.0**	**$760.1**	**$669.1**	**20%**

a Estimates. **b** Actual. **Note:** Obligations. **Source:** National Science Foundation

Energy research at DOE down 11%

$ Millions	1984[a]	1983[a]	1982[b]
Energy supply R&D	**$2036.6**	**$2071.0**	**$2350.8**
Nuclear fission	848.2	815.8	1088.5
Magnetic fusion	467.0	447.1	417.2
Supporting research and technical analysis	408.5	328.3	305.5
Environmental research	210.6	227.2	213.6
All other	102.3	252.6	296.0
Defense R&D and testing	**1380.1**	**1184.8**	**1088.3[a]**
General science and research	**645.2**	**542.6**	**529.4**
Fossil R&D	**94.0**	**217.6**	**417.7**
Conservation	**101.3**	**410.2**	**447.6**
TOTAL	**$4257.2**	**$4426.2**	**$4833.8**

a Estimates. **b** Actual. **Note:** Obligations. **Source:** Department of Energy, Office of Management & Budget

All NSF chemical research is up

$ Millions	1984[a]	1983[a]	1982[b]	% change 1983–84
Chemistry	**$ 80.1**	**$ 66.1**	**$ 61.3**	**21%**
Chemical dynamics	15.6	13.1	12.2	19%
Structural chemistry and thermodynamics	15.4	13.2	12.2	17
Chemical physics	12.8	10.9	10.0	17
Chemical instrumentation	9.8	6.3	5.9	55
Synthetic organic, natural products chemistry	9.7	8.1	7.5	20
Synthetic inorganic and organometallic chemistry	8.4	7.2	6.7	17
Chemical analysis	8.4	7.3	6.8	15
Chemical and process engineering	**27.0**	**22.2**	**20.3**	**22**
Chemical, biochemical processes	5.8	4.5	4.1	28.8
Kinetics, catalysis, and reaction engineering	4.5	3.6	3.3	25
Thermodynamics and transport phenomena	4.2	3.5	3.4	20
Particulate, multiphase processes	3.9	3.4	3.1	15
Engineering energetics	3.8	3.3	3.3	15
Minerals and primary materials processing	2.5	2.1	1.7	19
Separation processes	2.3	1.8	1.4	28
Biochemistry	**12.9**	**11.1**	**10.7**	**16**
Marine chemistry	**12.3**	**11.1**	**10.3**	**11**
Solid-state chemistry	**8.0**	**6.5**	**6.0**	**23**
Experimental and theoretical geochemistry	**7.2**	**5.3**	**5.8**	**36**
Atmospheric chemistry	**6.9**	**5.7**	**5.1**	**21**
Polymers	**6.6**	**5.4**	**5.3**	**22**
Mantle geochemistry	**4.0**	**3.1**	**2.2**	**29**
TOTAL	**$165.0**	**$136.5**	**$127.0**	**21%**

a Estimates. **b** Actual. **Note:** Obligations. **Source:** National Science Foundation

Defense gets another huge increase

$ Millions	1984[a]	1983[a]	1982[b]
Strategic programs	$ 8,978	$ 5,747	$ 4,846
Tactical programs	8,705	7,222	6,750
Technology base	3,555	3,137	2,945
Intelligence and communications	3,474	2,686	2,104
Program management and support	3,236	2,869	2,538
Advanced technology development	1,211	826	750
TOTAL	**$29,159**	**$22,487**	**$19,933**

a Estimate. **b** Actual. **Note:** Obligations. **Source:** Office of Management & Budget

USDA budget falls for the first time

$ Millions	1984[a]	1983[a]	1982[b]
Agricultural Research Service	$472.4	$468.9	$426.0
Cooperative State Research Service	231.7	245.0	219.0
Forest Service	104.4	110.2	114.4
National Agricultural Library	11.2	10.0	8.7
TOTAL	**$819.7**	**$834.1**	**$768.1**

a Estimate. **b** Actual. **Note:** Obligations. **Source:** Office of Management & Budget

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NASA shows slight drop in R&D funding

$ Millions	1984[a]	1983[a]	1982[b]
Conduct of R&D	**$1708.3**	**$1718.4**	**$2179.6**
Physics and astronomy	514.6	484.3	333.0
Aeronautical research	300.3	312.7	258.4
Space and terrestrial applications	289.0	397.6	319.0
Planetary exploration	205.4	208.7	198.0
Space transportation systems	183.0	117.0	890.0
Space research and technology	138.0	131.4	117.8
Life sciences	59.0	58.7	51.4
Tracking and data acquisition	22.0	8.0	12.0
Research and program management	**762.0**	**787.0**	**905.0**
R&D facilities	**92.2**	**160.2**	**156.3**
TOTAL	**$2562.5**	**$2665.6**	**$3240.6**

a Estimate. b Actual. **Note:** Obligations. **Source:** Office of Management & Budget

EPA's research effort takes another beating

$ Millions	1984[a]	1983[a]	1982[b]
Air	$ 51.2	$ 59.4	$ 63.1
Hazardous waste	27.4	33.0	29.2
Toxic substances	23.8	27.2	34.1
Energy	23.5	25.0	65.7
Drinking water	20.9	23.3	30.9
Water quality	19.2	30.5	53.5
Interdisciplinary	18.1	7.1	6.6
Program management	8.7	8.7	3.7
Superfund	6.4	6.5	13.8
Pesticides	6.1	6.6	7.1
Radiation	0.2	1.7	2.6
TOTAL	**$205.5**	**$229.0**	**$310.3**

a Estimate. b Actual. **Note:** Obligations. **Source:** Environmental Protection Agency

NIH R&D gain is almost invisible

$ Millions	1984[a]	1983[b]	1982[b]
National Institutes	**$3741.5**	**$3699.7**	**$3423.0**
Cancer	990.3	984.6	987.4
Heart, Lung & Blood	628.2	622.9	559.8
Arthritis, Diabetes & Digestive & Kidney Disease	419.6	412.4	368.2
General Medical Sciences	375.0	369.8	340.0
Neurological & Communicative Disorders & Stroke	301.1	295.8	265.5
Allergy & Infectious Diseases	282.7	275.0	237.4
Child Health & Human Development	257.4	253.7	226.2
Environmental Health Services	167.1	170.4	153.9
Eye	143.6	141.9	130.7
Aging	95.8	94.2	81.8
Dental Research	80.7	79.0	72.1
Research resources	**229.7**	**214.9**	**185.1**
National Institute for Occupational Safety & Health	**52.3**	**49.5**	**53.0**
National Library of Medicine	**52.1**	**49.2**	**46.1**
Office of the Director	**40.0**	**38.9**	**34.8**
Research facilities	**22.8**	**29.1**	**10.5**
John E. Fogarty Center	**15.1**	**13.8**	**9.5**
TOTAL	**$4153.5**	**$4095.1**	**$3762.0**

a Estimate. b Actual. **Note:** Obligations. **Source:** Office of Management & Budget

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conduct research in ultraviolet astronomy. One item not mentioned in the Administration wrapup of NASA-sponsored projects is a permanent, manned space station, an idea for which many believe the time has come, considering the success of the space shuttle.

There is no need for any belt-tightening whatsoever at NSF, and director Edward A. Knapp is excited and pleased by the opportunities offered by a proposed overall budget increase of 18%. This year everything would be up, even science and engineering education, which were all but phased out in the 1983 budget request. Funding would be up $9 million to $39 million. Of that increase, $4 million would be used to raise the stipend and cost-of-education allowance for NSF's 1390 graduate fellows. The stipend would be increased from $6900 to $8100, and the cost-of-education allowance would be increased from $4000 to $4900.

Funding for NSF's research programs would be up more than 18% to $1.2 billion and NSF would use a large part of that $186 million increase to boost average grant sizes. In chemistry, for example, project support would be increased 15.1%, or $8.1 million, to $61.9 million.

NSF is also planning on increasing its support of research instrumentation. Foundationwide, this support would increase 100% over fiscal 1982 levels. The fiscal 1983–84 increase is 60.5% to $180.2 million. Support for research equipment and instrumentation by the directorate of mathematical and physical sciences would be up 53% to $86.3 million. Support for acquisition of equipment in the intermediate cost category (between that normally provided in research awards and that made available through major laboratories and national facilities) would be increased $7.7 million, or 61.1%, to a total of $20.3 million.

Graduate student support also would be expanded in fiscal 1984, with the number of graduate students supported on research projects expected to increase 797 to 10,428; the amount of support provided to them would be up 16.2% to $92.7 million. The number of graduate students supported by grants from the directorate of mathematical and physical sciences would increase 323 to 4332. Their support would increase 20% to $40.3 million.

In the budget proposal it appears that only funding for the directorate for scientific, technological, and international affairs (STIA) would decrease in fiscal 1984, from $44.2 million to $36.8 million. But according to Knapp, that decrease would be only on paper, because an additional $22.1 million would be provided for the programs usually funded by STIA from within NSF's discipline-oriented research programs. Out of STIA's budget would come funds for three or four new industry/university cooperative research centers and six to 10 planning grants for additional centers, as well as a 16.7% increase in the industry/university cooperative research program. It also would provide increased support for new research efforts in risk analysis, an area of growing importance in the regulatory policy area.

Funds from the research programs would provide $5.9 million for support of research conducted under bilateral agreements, plus an additional $2.0 million to initiate a new U.S./India program; up to $3 million for a new program to encourage independent faculty research at predominantly four-year colleges; $2.5 million for the experimental program to stimulate competitive research to fulfill existing commitments while the program is being phased out; and $500,000 for visiting professorships for women.

In addition, the proposed budget includes approximately $6 million for first-year support for up to 200 Presidential Young Investigators Research Awards. Faculty members who are within seven years of their Ph.D. are eligible for the awards, which will average about $30,000 per year. Matching funds from private sources are required.

The Department of Agriculture was not as fortunate as NSF. USDA maintains its position as one of the largest federal funders of R&D, but, for the first time in recent memory, its total R&D budget would fall. Much of the cut would come from the competitive grants program, with another $4 million cut from forestry research.

The largest program, the Agricultural Research Service, would be effectively frozen at the fiscal 1983 level of about $470 million. According to the Administration, in 1984 increased emphasis will be placed on research on genetic engineering in the plant and animal sciences, human nutrition, and postharvest technologies. A new program of postdoctoral fellowships in ARS labs is also planned.

The reason for so small an increase is mainly that short-term applied research is being reduced because it belongs more appropriately in the private sector, Administration officials say.

At the Cooperative State Research Service, a drop in funding of about 5% would mean fewer competitive grants distributed for research. But at the same time, the Administration would expand the program to start giving grants for research in animal sciences.

The Forest Service's R&D program would be cut about 4%, and would have to continue its work on such areas as genetics, silviculture, wildlife habitats, and forest product production at a reduced rate.

According to a special analysis of the budget by the Office of Management & Budget, obligations for R&D at the Department of Interior would be down $44 million to $329 million in fiscal 1984, with most of the cuts coming in the areas of applied mining and applied geological research. Almost 90% of Interior's 1984 funds would be accounted for by the Geological Survey ($136 million), Fish & Wildlife Service ($89 million), and the Bureau of Mines ($68 million). Although that last figure represents a reduction in funding for the Bureau of Mines, it still would be expected to increase its basic research 22%, particularly in the area of strategic and critical minerals. High priority would be given to long-range, high-risk research in extractive metallurgy technology and development of U.S. source substitutes for imported minerals.

The Department of Commerce's research funding would be cut under the budget proposal, not slightly as is Agriculture's, but severely. Overall, R&D funding would be down 27%, or $86 million, to $227 million. The National Oceanic & Atmospheric Administration's research budget would be cut 30% to $135 million. The decreases, according to budget documents, "are primarily in applied areas, more appropriately supported by the private sector."

The National Bureau of Standards is equally hard hit. Its total budget would be down 24% to $94.2 million. Totally eliminated from the budget request are the Center for Fire Research, which supports most basic and applied university fire research, and the Center for Building Technologies; both do a more-than-decent amount of chemical research. Also eliminated are the programs on automated data processing standards and recycled oil. Proposed cuts include measurement research and standards, 3% to $48.7 million; core measurement research for new technologies, 6% to $12.0 million; engineering measurements and standards, 18% to $18.5 million; and central technical support, 71.7% to $4.5 million. The only program that would gain is technical competence, up 7% to $7.7 million.

Few areas of research have been more controversial in recent years than the programs of the Environmental Protection Agency. The Reagan Administration has steadily slashed away at EPA's research, and Congress has attempted to restore some of the funding. This year, the agency has requested a 6% further cut in R&D, down to $206 million from fiscal 1983. Although not as large a cut as requested in previous years, EPA's R&D budget would still be one third lower than it was two years ago.

According to the Administration, the cuts reflect efficiencies and policy changes in environmental research. Three major concerns are better linkage of research to the agency's regulatory priorities, greater attention to quality assurance to improve the reliability of data used by EPA in making regulatory decisions, and a restructuring of the agency's long-range R&D program.

The biggest reduction would come from cutting development work on control technologies in the areas of air quality, municipal and industrial wastewater treatment, and hazardous spills.

Other large cuts would result from EPA's completion of its Great Lakes water quality program and the elimination of the nonionizing radiation health effects research project.

Some small increases are proposed by the agency for fiscal 1984 R&D. These include a $2.1 million raise for evaluation of air pollutants, especially for updating the ambient air quality standards. Acid rain is another area that would receive increased support over 1983, as are health effects of toxic chemicals, quality assurance work in pesticides and drinking water, and Superfund research.

Although the cuts may not seem severe—indeed, they are not as heavy as in some other R&D agencies—Congress has been in the mood to support environmental research and can be expected to try to raise EPA's research funding budget.

The pattern in the past few years, with the exception of the defense R&D budget, has been for Congress either to accept the Administration's budget proposals for increases in R&D funding, or to beef up funding where large cuts had been proposed. That pattern is likely to hold true this year. □

Analytical Instrument Sales Set To Bounce Back After Recession

Industry remains basically sound and basically American, thanks to big home markets, hefty exports, and continued innovation by U.S. firms

Stephen C. Stinson, C&EN New York

It doesn't look good on the surface. Worldwide sales of laboratory analytical instruments may drop about 1% in 1983 from 1982, and 1982 sales were about level with those in 1981. This performance looks like hard times for an industry with past and predicted future growth rates of 9 to 11% per year in constant dollars.

But 1981 and 1982 didn't do that much damage. Analytical instruments are still a robust and profitable business with potential to soar again after the world's current economic decline. And from the view of U.S. instrument makers, it is a distinctly American business, fueled by large markets in the U.S., hefty exports, and home-grown technological advances.

Exact sales data are hard to come by for many areas of the laboratory analytical instrument field. One source is a study by the laboratory instruments consulting firm Alpert & Sutcliffe of Stamford, Conn. C&EN has revised these data slightly to account for a delayed economic upturn, whose time always seems to lie about nine months in the future.

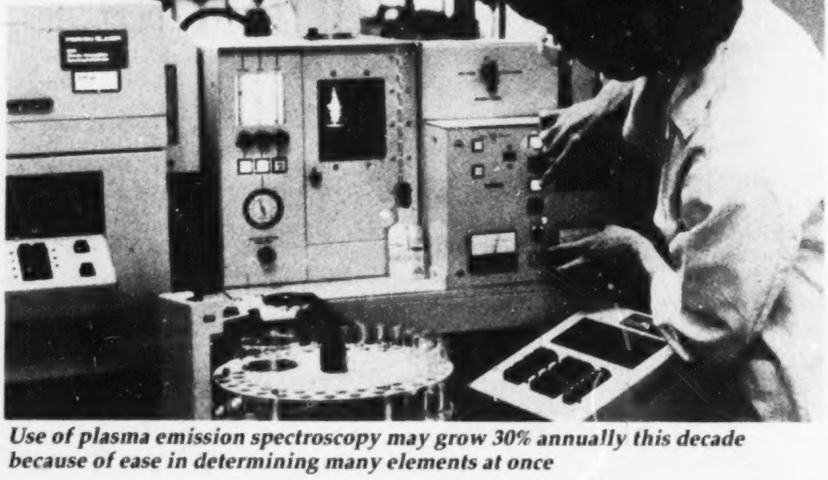
According to these estimates, worldwide sales of laboratory analytical instruments may be a little more than $2.2 billion in 1983, with U.S. customers buying about $1 billion. This U.S. market includes about $185 million in imports. Of the $1.2 billion market outside the U.S., American exports may comprise $800 million.

So instrument foreign trade favors the U.S. decisively. Imports of instruments to the U.S. were growing more than 25% annually in the late 1970s, but exports rose 35% per year, according to data from the Bureau of the Census.

One reason for U.S. leadership in analytical instruments has been its technology. For example, the 15-year trail that led to today's $300 million-per-year market in high-performance liquid chromatography (HPLC) was blazed almost singlehandedly by Waters Associates of Milford, Mass. Also, U.S. instrument makers capitalized on American strength in microprocessors in the mid-1970s to bring on the first generation of "smart" machines. Minicomputers from U.S. technology rendered routine such techniques as mass spectrometry (MS), Fourier transform infrared (FTIR) spectrometry, and nuclear magnetic resonance (FT-NMR) spectrometry. The strategy of U.S. producers in the 1980s is to consolidate their dominance with computer programs to operate instruments, reduce data, and manage lab traffic.

A second reason behind the strong U.S. position in its own markets is the difficulty of establishing adequate service and applications networks in the U.S. Such foreign-controlled firms as Bruker Instruments, Pye Unicam, and Shimadzu Corp. have made important inroads, but their U.S. sales pale beside those of U.S. giants like Hewlett-Packard, Perkin-Elmer, SmithKline Beckman, Varian Associates, and the dozen of more specialized firms here.

Competition for analytical instruments sales in the U.S. has intensified, however, and the major task for U.S. firms in the 1980s is to meet the challenge. As Perkin-Elmer executive vice president Gaynor N. Kelley testified to the House Finance Committee in 1981, "The giants of Japanese technology have identified the analytical instrument business as one targeted for increased market pene-



Use of plasma emission spectroscopy may grow 30% annually this decade because of ease in determining many elements at once tration worldwide. The survivors in this contest will be those who have successfully married the analytical techniques to the computers that are automating much of the laboratory work up to and including laboratory management.

"It is a very real possibility that we can expect to see our profitability vs. our investment dollar falling as a consequence of Japanese competition—unless we can continue to introduce better instrumentation products through long-term research and development commitments."

In the recent past, that profitability has been considerable. Among the larger, publicly held firms that report results for their analytical instrument businesses, Hewlett-Packard is a case in point. Sales grew at annual rates of 25 to 30% at the end of the 1970s, and operating profits (pretax earnings) at 25 to 30% as well. Operating profits were a highly respectable 15% of sales and 20 to 30% of assets. In the fiscal year ended Oct. 31, 1982, however, sales fell 4% to $177 million, and operating profit declined 10% to $28 million. Still, even in these depressed conditions, operating profit was 16% of sales and 27% of assets.

Perkin-Elmer's instrument group sales rose 20 to 25% per year in the late 1970s, and operating profit increased 10 to 40% annually. Also, operating profit has been 15 to 20% of assets and 12 to 15% of sales. In the 1982 fiscal year (ended July 31), though, sales were down 1.5% to $324 million, and operating profit was down 11% to $44 million. Even so, that profit was 14% of sales and 19% of assets. In the next quarter, sales continued down.

For Varian, the picture is less clear because of a shift of businesses out of the analytical instrument group in 1979. Sales probably grew up to 30% per year at the end of the seventies, but operating profit was only 4 to 10% of sales and 3 to 8% of assets. In fiscal 1982 ended Sept. 30, however, sales were off 10% from fiscal 1981 to $124 million and operating profit was down 10% to $4.5 million.

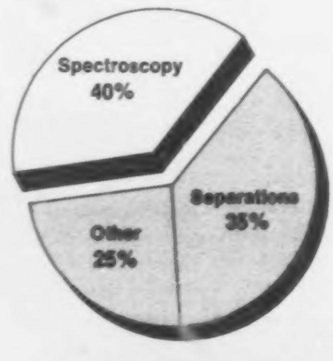
This overall health of the laboratory instrument business makes acquisitions in this industry attractive. Allied Corp. will acquire Instrumentation Laboratory, Wilmington, Mass. Allied will pay $110 million for the company, half in cash and half in Allied stock as part of a tax-free merger.

Analytical instruments: guidelines for inclusion

In preparing this article, C&EN has adopted the definitions of laboratory market consultants Alpert & Sutcliffe, Stamford, Conn., for analytical instruments. Analytical instruments are instruments that have general or broad use in chemical analysis. These do not include instruments that make mere physical measurements. Thus color analyzers and electronic balances are excluded. Also excluded are instruments too highly dedicated to one use, as in clinical laboratories, and those used to monitor or control processes on-line. Therefore scintillation counters, which are used in research, are included, but gamma counters, used almost entirely in clinical work, are not. Again, instruments for separate quality control testing are included, but detectors that operate as parts of larger, on-line process control systems are not.

Instrumentation Laboratory reported earnings of $4.6 million on sales of $138 million for fiscal 1982 ended March 31, but suffered losses in the next three quarters. Allied chairman Edward L. Hennessy Jr. expects to turn the financial picture at IL around by applying the marketing strength of Fisher Scientific, which Allied acquired in 1981. What attracted Hennessy to IL was the company's line of clinical diagnostic instruments and supplies, which forms 85% of IL's business. IL also has an analytical instruments division, however, which produces such instruments as atomic absorption spectrometers.

Spectroscopy is largest instrument market



Total 1983 global market = $2.24 billion

Sources: Alpert & Sutcliffe; C&EN and industry estimates

Several factors recently have affected sales of laboratory analytical instruments, with some types of instruments affected more than others. Among these factors is a depressed business climate, which has resulted in lower-than-usual increases in research and development budgets in customer industries. Increases in government funding for university research also have been small. In the government itself, there has been a shift away from energy projects but a large increase in defense spending.

A C&EN survey of R&D spending by 15 chemical producers indicates that outlays in 1983 will be up only 5% in 1983, compared with a 13% increase in 1982 and 20% increases for 1981 and 1980 (C&EN, Jan. 17, page 17). The chemical industry is the biggest user of analytical instruments, and its 1983 R&D spending may just balance out effects of inflation.

Nelson L. Alpert of Alpert & Sutcliffe says sales of costly research instruments in the $100,000 to $300,000 range may suffer more than those of less expensive systems. Thus mass spectrometry, Fourier transform NMR, and electron microscopy could be especially hard hit. On the other hand, purchases of instruments for quality control laboratories may fare better, because these have obvious and identifiable contributions to productivity, according to Alpert.

Perkin-Elmer president Horace G. McDonnell Jr. pointed out to security analysts last November that "what gets hardest hit are those product lines where operation of the equipment is not destructive to the equipment. Usually, what's hit hardest in recessions is spectroscopy products." Slow but steady wear and tear from heat in gas chromatographs and pressure in liquid chromatographs, for example, result in slightly higher needs to replace chromatographs than spectrometers, even during hard times.

Analytical instrument makers would reap a bonanza if universities could find a source for the $1.5 billion to $2 billion estimated by the Department of Defense that they need to buy replacements for obsolescent instruments.

A few tens of millions of dollars may be forthcoming from various government agencies in 1983 for this purpose (C&EN, Nov. 8, 1982, page 25). There also have been a few highly publicized research arrangements between universities and industry. But the sum of these efforts falls far short of universities' needs.

Far more promising is the 10% increase in R&D spending to $5.9 billion in 1983 for various government agencies, much of which might be granted to universities (C&EN, Jan. 24, page 7). Increased productivity among instrument and semiconductor producers has kept inflation rates for instruments at about 6% per year, according to Alpert, even in those years when the consumer price index soared. Thus these government grant increases may improve the fortunes of instrument makers somewhat.

For the government itself, some observers have suggested that large increases in defense spending would more than balance the 5% drop in funding to the Department of Energy. DOD accounts for 50% of all government analytical instrument purchases, Alpert notes. Nevertheless, relatively little of defense increases may go for instruments. A more likely source of benefit to instrument makers may be orders from firms that get increased DOD orders for weapons and material.

Among specific types of instruments, high-performance liquid chromatographs may be the largest single best sellers, and their sales are growing at almost the highest rate of any. Worldwide sales of HPLC instruments will be $300 million in 1983, the same as in the two previous years, with about half of these instruments bought in the U.S. Later in the 1980s, HPLC sales may grow at 25% per year in current dollars, largely because of taking some market share away from gas chromatographs.

Reasons for customers' preferring liquid to gas chromatography for separating complex mixtures include the ability to apply LC to four to five times as many compounds as GC, which requires thermally stable volatile compounds; the usual relative lack of need to "clean up" samples for LC; and the fact that the 10,000 theoretical plates for an LC column are sufficient for most separations. But LC suffers from lack of a universal detector, such as flame ionization for GC; use of costly solvents; the greater difficulty of programing reproducible solvent gradients for LC than temperature profiles for GC; and the requirement for some separations of hundreds of thousands of theoretical plates offered by GC columns. Another reason why LC will never drive out GC completely is that GC was there first. Gas chromatographs already are established in laboratories, as are the routine methods for using them where they work.

Gas chromatograph sales and those of supplies and accessories have been a flat $300 million during 1981, 1982, and continuing into 1983. This includes $115 million U.S. sales in each year. Nevertheless, improved columns, sample injectors, and detectors, as well as already successful interfacing of gas chromatographs with spectrometers of various types, point to continuing success for GC, sales of which likely will grow at 20% annually this decade.

By the same token, HPLC will never replace the last atmospheric-pressure liquid column chromatograph. This is because many investigators in the life sciences fear that high pressures of HPLC may degrade their sensitive samples. In addition, column chromatography uses smaller volumes of costly solvents than HPLC. Sales of column chromatographs thus will be a hefty $150 million around the world, and U.S. chemists will take half of that. As world economies resume growth, column chromatograph sales may rise at 12% annually.

But amino acid analyzers may suffer more than GC or column chromatography from HPLC competition. These analyzers are really highly dedicated HPLC instruments, and there is little incentive to buy such specialized equipment when an existing HPLC can be adapted so readily to amino acid analysis. World sales of amino acid analyzers probably will reach $27 million in 1983, including $10 million in the U.S. These sales volumes actually may decline slightly in later years.

Hewlett-Packard has tried to solve the problem of the universal LC detector by adapting its diode-array ultraviolet-visible spectrophotometer to this use. This device samples each LC peak with many rapid bursts of light, diffracts the analyzing beam with a grating toward a string of diode detectors, and records the number of "counts" at any wavelength. If the price can be made affordable, the technique may become the closest approach yet to routine universality.

Some workers see microbore columns as a means to reduce solvent consumption. Microbore columns have the same 25-cm length as conventional ones, but internal diameters are 1 mm rather than 4.6 mm. Microbore columns use 3 μm-particle packing instead of 5 μm- to 10-μm-particles of conventional ones. As a result, microbore columns reduce solvent consumption 95%.

An alternative is to use columns only 3 to 5 cm long, with the usual 4.6-mm internal diameters and 3 μm-particles. In addition to reducing solvent consumption 90%, these short columns reduce analysis time 95% in comparison with microbore or conventional columns and cost about half as much. The number of theoretical plates is only 5000, but that still may be enough for most analyses.

Other advances that would increase the utility of HPLC would be successful interfacing with such instruments as infrared and mass spectrometers, as already has been done for GC. Such techniques give information about molecular structures of components as fast as they are separated in mixtures. In HPLC-MS combinations, the problem is what to do about the large excess of solvent that carries the solute to be analyzed. For HPLC-IR, difficulties arise in scanning such dilute solutions and from interfering infrared absorptions of solvents.

For mass spectrometry, the Hewlett-Packard interface vaporizes solvent and solute and admits a minute amount of the vapor to the spectrometer through a 5-μm hole. Solvent vapor serves as reagent gas in the ensuing chemical ionization. The approach of Finnigan MAT is to coat a moving belt or wire with the effluent solution, and evaporate the solvent before the moving zone reaches the spectrometer ion source. The still experimental method of Sciex divison of MDS Health Group (Thornhill, Ont.) is HPLC-MS-MS, which vaporizes the solution, analyzes the vapor in one mass spectrometer following chemical ionization, selects one solute ion, and analyzes that ion in a second mass spectrometer, free of other species.

To solve the problems of HPLC-IR, D. Warren Vidrine, a chemist for Nicolet Instrument, has advocated both use of solvents that do not have interfering infrared absorbances in the region of interest and use of computer-minded subtraction of what interfering absorbances there are (C&EN, Jan. 12, 1981, page 26). Others object that infrared-transparent solvents are not always the best ones for HPLC. Also, subtraction of interfering peak works well with weak absorbances, but not always with strong ones. Chemistry professor Peter R. Griffiths of the University of California, Riverside, prefers to collect effluent solution onto potassium chloride plates, evaporate the solvent, and analyze the solute residue by diffuse reflectance infrared techniques.

Analytical instruments recovery will start in 1984

World sales, $ millions	1981	1982	1983	1984	1985
MOLECULAR ANALYSIS					
Ultraviolet/visible	$ 158	$ 160	$ 158	$ 168	$ 181
Dispersive infrared	77	71	71	76	89
Fourier transform-infrared	21	19	19	24	37
Fluorescence	45	46	45	49	54
Raman	7	7	7	7	8
Polarimetry	6	6	6	7	8
Nuclear magnetic resonance	60	55	55	60	72
Electron spin resonance	9	9	9	9	10
Gas chromatography	300	300	300	348	410
High-performance liquid chromatography	300	300	300	361	455
Amino acid analysis	27	27	27	28	29
Column chromatography	168	172	168	184	206
Mass spectrometry	162	150	150	168	207
Densitometry	38	39	38	41	45
Thermal analysis	66	71	71	76	82
ELEMENTAL ANALYSIS					
Atomic absorption	130	117	117	126	149
Arc/spark	71	72	71	75	80
Inductively coupled plasma-atomic emission	61	70	70	80	103
Energy-dispersive x-ray	39	40	39	44	51
Wavelength-dispersive x-ray	71	73	71	78	87
X-ray diffraction	40	41	40	44	50
Electron spectroscopy	31	32	31	34	38
Scanning electron microscopy	85	87	85	95	108
Transmission electron microscopy	32	32	32	33	35
Electron probe	23	23	23	24	25
Organic elemental analysis	44	45	44	48	53
OTHER					
Ion chromatography	18	19	18	22	28
Voltammetry/polarography	22	24	22	28	38
pH- and ion-specific electrodes	81	83	81	88	97
Titration	27	27	27	29	31
Vacuum ultraviolet	7	7	7	8	10
TOTAL	**$2268**	**$2266**	**$2244**	**$2504**	**$2918**

Source: Alpert & Sutcliffe; C&EN and industry estimates

Besides gas and liquid chromatography, other important instrument markets include atomic absorption spectroscopy (AAS) and inductively coupled plasma-atomic emission spectroscopy (ICP-AES), and direct-current plasma-AES. World AAS sales were down 10% in 1982 to $117 million, of which $45 million were U.S. sales. Sales are expected to be flat for 1983. Replacement sales, increasing costs of more sophisticated sampling techniques, and inflation could lead to 8% annual current-dollar growth rates in this mature market in the 1980s.

Sales of plasma spectrographs rose 15% in 1982 to $70 million worldwide, with half of that in the U.S. Sales in 1983 likely will remain steady, but these instruments have a potential for 30%-per-year growth rates in the rest of the decade.

The attraction of the relatively newer plasma spectroscopy lies in its ability to analyze for many elements simultaneously or in automatic sequence. In addition, growing unit volume could lower production costs, further attracting buyers. Still, plasma spectroscopy never will completely replace AAS, because plasma spectrographs cost six to 15 times as much as AAS instruments, and because plasma spectrographs are limited largely to liquid samples. Some progress has been made in getting away from the liquid sample limitation as workers develop gaseous hydride techniques to analyze for such elements as arsenic and selenium.

Ultraviolet/visible spectrophotometers are another large, but mature, market. World sales will be about $158 million in 1983, including $60 million in the U.S. These sales could increase 8% yearly in current dollars, after economic recovery, owing to inflation and replacement of older instruments. Growth rates could be larger as a result of Hewlett-Packard's development of a diode-array UV/Vis spectrophotometer, but the price of these instruments is still quite high. □

Chemical earnings hit bottom
Page 14

FEBRUARY 14, 1983

CHEMICAL & ENGINEERING

NEWS

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Catalysis

Metal complexes bring new selectivity to bond activation

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CHEMICAL & ENGINEERING NEWS

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Chemical Earnings Fell Again in Fourth Quarter

William J. Storck and David Webber,
C&EN New York

The fourth quarter of 1982 ran true to form as far as earnings of U.S. chemical producers were concerned. Like the three previous quarters, earnings for chemical companies, as well as oil companies and diversified manufacturers that produce chemicals, fell—and fell hard.

The only hope now is that 1983 will be better. And early signs show more health in the economy in the first quarter of this year than there has been for some time.

On a strict year-to-year basis, it seemed reasonable to assume that the fourth-quarter drop in chemical earnings might not be as large as in the three previous quarters of 1982, since fourth-quarter 1981 was fairly weak. However, this was not to be the case. Chemical companies performed almost as poorly in the fourth quarter as in the earlier three-month periods, with earnings falling 32% from fourth-quarter 1981.

Again, low demand and falling prices were the primary reasons for the drop in earnings. In the fourth quarter of 1982, prices dropped, according to government figures, an average of 0.9% from their year-earlier level. This was the second quarterly drop in the average producer price index in the year and also the largest.

In the third quarter, prices decreased an average of 0.4%. Production in the fourth quarter also declined because of depressed demand, as it had done in the four previous quarters. The average drop in chemical production in the fourth quarter was about 5.4%. This, however, was less than the 10.9% decline in the third quarter, the 11.2% fall in the

Chemical industry leaders for fourth quarter . . .

Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1981		$ Millions	Rank 1981		Earnings as % of sales	Rank 1981
1	Dow Chemical	$ 2561.0	1	Allied Corp.	$ 54.0	2	Freeport-McMoRan	11.1%	1
2	Union Carbide	2280.0	2	W. R. Grace	54.0	3	Nalco Chemical	9.4	3
3	W. R. Grace	1592.2	3	FMC	45.7	5	Petrolite	9.4	2
4	Monsanto	1466.2	5	Monsanto	42.3	6	Stauffer Chemical	7.2	5
5	Allied Corp.	1444.0	4	PPG Industries	41.6	7	Loctite	7.0	6
6	FMC	886.4	7	Union Carbide	30.2	1	First Mississippi	6.9	2
7	PPG Industries	821.2	8	Air Products	28.0	10	Ethyl	6.8	12
8	Celanese	710.0	6	Ethyl	26.1	14	International Minerals	6.7	7
9	Hercules	576.0	9	Hercules	22.4	16	FMC	5.2	10
10	National Distillers	453.6	10	International Minerals	21.7	12	PPG Industries	5.1	14

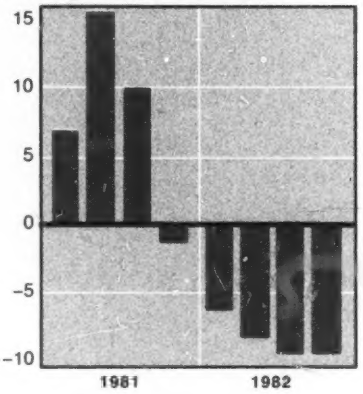
. . . and for full-year 1982

Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1981		$ Millions	Rank 1981		Earnings as % of sales	Rank 1981
1	Dow Chemical	$10,618.0	1	Monsanto	$347.0	3	Freeport McMoRan	11.1%	1
2	Union Carbide	9,060.0	2	Dow Chemical	342.0	1	Nalco Chemical	10.0	2
3	Monsanto	6,325.8	3	Union Carbide	309.7	2	Petrolite	9.7	3
4	Allied Corp.	6,167.0	5	Allied Corp.	280.0	4	Stauffer Chemical	7.3	4
5	W. R. Grace	6,127.6	4	W. R. Grace	254.4	5	Air Products	6.9	5
6	FMC	3,498.8	7	PPG Industries	155.1	6	Loctite	6.4	11
7	PPG Industries	3,295.5	8	FMC	152.4	7	First Mississippi	6.2	7
8	Celanese	3,062.6	6	Stauffer Chemical	117.5	9	Ethyl	5.8	14
9	Hercules	2,469.0	9	Air Products	108.4	14	Monsanto	5.5	12
10	National Distillers	1,831.3	10	Hercules	98.4	12	International Minerals	4.9	5

a After taxes. **Note:** For 40 companies listed on page 16.

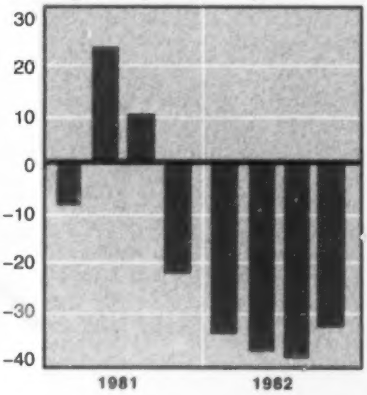
Chemical industry 1982 fourth-quarter results

- **Sales dropped 9%**
- **Earnings plunged 37%**
- **Profitability fell again**
- **Production sank 5.4%**
- **Prices slipped 0.4%**



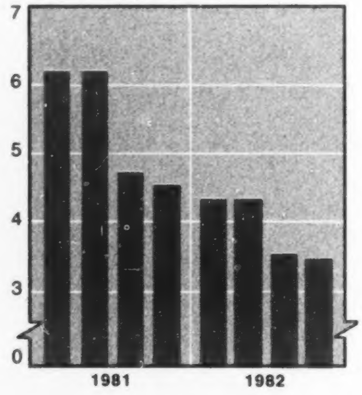
Sales

% change from year-earlier quarter



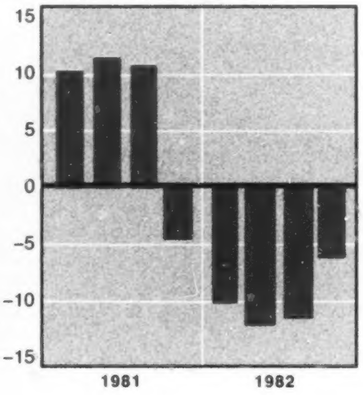
Earnings

% change from year-earlier quarter



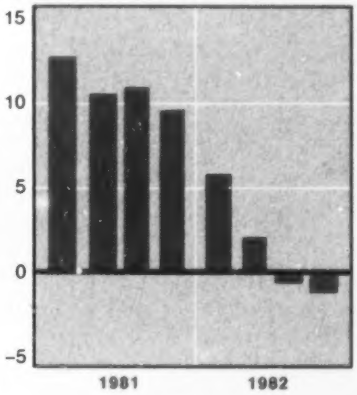
Profit margins

After-tax earnings as % of sales



Production

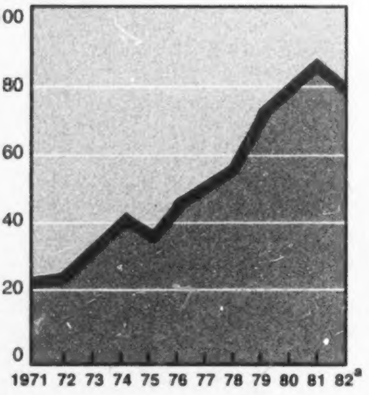
% change from year-earlier quarter



Prices

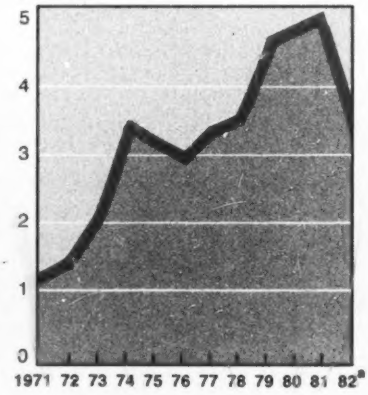
% change from year-earlier quarter

Sales in 1982 fell about 8%, and earnings dropped more than 33%, pushing profitability down to about 4.1%



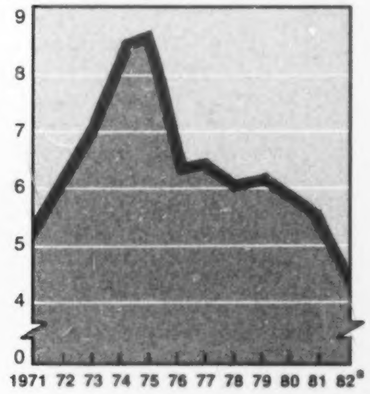
Annual sales

$ Billions



Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales

[a] **C&EN estimates. Note:** All sales, earnings, and profit-margin data are based on the combined performance of the 40 largest chemical makers listed on page 16.

Earnings for chemical firms were down more than 32% for both fourth quarter and full year

	FOURTH-QUARTER 1982						FULL-YEAR 1982			
	Sales	Earnings	Change from 1981		Profit margin[a]		Sales	Earnings	Change from 1981	
	($ millions)		Sales	Earnings	1982	1981	($ millions)		Sales	Earnings
Dow Chemical[d,e]	$ 2,561.0	$ 13.0	−14%	−81%	0.5%	2.2%	$10,618.0	$ 342.0	−11%	−39%
Union Carbide	2,280.0	30.2	−6	−78	1.3	5.8	9,060.0	309.7	−11	−52
W. R. Grace[f]	1,592.2	54.0	−10	−35	3.4	4.7	6,127.6	254.4	−6	−23
Monsanto[g]	1,466.2	42.3	−6	−18	2.9	3.3	6,325.8	347.0	−9	−8
Allied Corp.[h]	1,444.0	54.0	−15	−41	3.7	5.4	6,167.0	280.0	−4	−18
FMC	886.4	45.7	1	−14	5.2	6.1	3,498.8	152.4	4	−14
American Cyanamid[i]	—	—	—	—	—	4.7	—	—	—	—
PPG Industries[e]	821.2	41.6	2	6	5.1	4.9	3,295.5	155.1	2	−27
B. F. Goodrich[i]	—	—	—	—	—	2.7	—	—	—	—
Celanese[j]	710.0	−15.0	−20	def	def	4.0	3,062.0	5.0	−18	−97
Hercules	576.0	22.4	−11	39	3.9	2.5	2,469.0	98.4	−9	−28
National Distillers	453.6	17.2	−13	−53	3.8	7.1	1,831.3	79.1	−10	−42
Morton-Thiokol[k]	423.7	20.8	—	—	4.9	—	1,076.0	52.3	—	—
Olin[l]	415.4	6.2	−7	−55	1.5	3.1	1,823.1	62.8	−9	−32
Stauffer Chemical[m]	398.7	4.2	6	−83	1.1	6.6	1,618.2	117.5	−6	−18
Air Products	388.1	28.0	4	−19	7.2	9.3	1,583.5	108.4	—	−16
Ethyl Corp.	383.6	26.1	−11	10	6.8	5.5	1,614.6	94.2	−8	4
Rohm & Haas	383.4	14.0	−7	1	4.1	3.4	1,828.0	75.2	−3	−23
Williams Cos.	358.9	4.7	−15	−23	1.3	1.4	1,691.3	29.7	−14	−70
International Minerals[n]	325.5	21.7	−12	−23	6.7	7.6	1,501.9	74.3	−16	−49
Witco Chemical[o]	303.7	7.7	−1	−31	2.5	3.7	1,305.4	27.9	1	−28
Pennwalt	219.6	0.0	−12	def	0.0	def	952.4	24.5	−10	−33
Lubrizol[i]	—	—	—	—	—	8.6	—	—	—	—
Freeport-McMoRan[p]	191.8	21.2	−4	−31	11.1	15.3	747.9	82.8	−11	−48
Reichhold Chemicals[q]	184.8	0.7	−12	−53	0.4	0.7	814.9	7.0	−14	−59
GAF[i]	—	—	—	—	—	def	—	—	—	—
Nalco Chemical	158.9	14.9	−11	−30	9.4	12.0	643.9	64.3	−3	−21
International Flavors[i]	—	—	—	—	—	12.5	—	—	—	—
Liquid Air[i]	—	—	—	—	—	7.2	—	—	—	—
H. B. Fuller Co.	96.6	2.0	17	−38	2.1	3.9	331.8	8.6	1	−37
Petrolite	71.6	6.7	−7	−12	9.4	9.9	302.6	29.3	2	5
Chemed[i]	—	—	—	—	—	7.0	—	—	—	—
Stepan Chemical[i]	—	—	—	—	—	4.2	—	—	—	—
Crompton & Knowles[r]	51.0	1.2	−10	−56	2.4	4.8	213.2	3.9	−12	−55
Loctite	50.2	3.5	−5	−17	7.0	8.0	212.5	13.6	−3	−1
First Mississippi	43.5	3.0	−34	−65	6.9	12.9	206.5	12.7	−41	−46
Greak Lakes Chemical[i]	—	—	—	—	—	9.5	—	—	—	—
Essex Chemical[i]	—	—	—	—	—	3.8	—	—	—	—
Philip A. Hunt	25.7	0.2	−13	def	0.9	def	114.8	5.3	3	40
Lawter International[i]	—	—	—	—	—	11.9	—	—	—	—
Total 18 larger companies	**$15,444.2**	**$510.3**	**−9.1%**	**−32.7%**	**3.3%**	**4.5%**	**$64,115.6**	**$2584.2**	**−8.2%**	**−33.1%**
Total 11 other companies	**$ 1,397.4**	**$ 61.1**	**−7.5%**	**−30.0%**	**4.4%**	**5.8%**	**$ 5,875.9**	**$ 279.9**	**−7.5%**	**−34.0%**
GRAND TOTAL	**$16,841.6**	**$571.4**	**−9.0%**	**−32.5%**	**3.4%**	**4.6%**	**$69,991.5**	**$2864.1**	**−8.2%**	**−33.2%**

a After-tax income as a percentage of sales. **b** Fully diluted before nonrecurring and extraordinary items. **c** As of Jan. 31. **d** Excludes $57 million extraordinary gain in 1982. **e** Includes nonrecurring items. **f** Excludes $65.1 million nonrecurring gain in 1982 and $34.9 million gain in 1981. **g** Excludes $67.7 million nonrecurring gain in 1981. **h** Excludes nonrecurring charge of $8 million in fourth-quarter and full-year 1982, $33 million charge in fourth-quarter 1981, and total $5 million gain for full-year 1981. **i** Not all information available at press time. **j** Excludes nonrecurring charge of $39 million in fourth-quarter and full-year 1982. **k** Since merger of Morton and Thiokol, previous quarterly figures have not been restated, making comparisons with

second quarter, and the 10.0% drop in the first quarter of 1982.

The drop in production was caused by the continuing problem of low demand for chemicals. There was little activity in housing markets for the chemical industry, affecting a wide range of products. And demand for autos, which use a lot of chemical products, continued to falter as consumer spending all but dried up.

Add to these downswings problems in the agricultural area and their effect on chemicals. Fertilizers and specialty agricultural chemicals had held up through the recession probably as long, if not longer, than most other chemicals. Finally, however, falling farm income caught up with them and drove down fertilizer production. Toward the end of last year, price cutting occurred even in pesticides.

The strength of the U.S. dollar

FULL-YEAR 1982 Profit margin[a]		Earnings per share[b]		STOCK MARKET DATA[c]					
					Recent 12 months		Price earnings ratio	Annual indicated	Dividend yield, %
1982	1981	4th qtr	Full year	Jan 31	High	Low	Jan. 31	dividend	of price
3.2%	4.8%	$\$0.07$	$\$1.77$	$\$28\frac{3}{4}$	$\$30\frac{3}{8}$	$\$19\frac{5}{8}$	16	$\$1.80$	6.3%
3.4	6.4	0.42	4.47	56	61	$40\frac{1}{8}$	13	3.40	6.1
4.2	5.0	1.11	5.18	$40\frac{1}{4}$	$45\frac{1}{2}$	$28\frac{1}{2}$	8	2.80	7.0
5.5	5.4	1.00	8.67	$83\frac{5}{8}$	89	$56\frac{5}{8}$	10	4.00	4.8
4.5	5.4	1.12	6.46	$34\frac{5}{8}$	$43\frac{1}{2}$	$28\frac{3}{4}$	5	2.40	6.9
4.4	5.2	1.27	4.23	$35\frac{5}{8}$	$37\frac{1}{2}$	$23\frac{3}{8}$	8	1.80	5.1
—	4.3	—	—	$35\frac{5}{8}$	$37\frac{1}{2}$	$24\frac{3}{8}$	12	1.75	4.9
4.7	6.3	1.20	4.51	$54\frac{7}{8}$	$57\frac{3}{4}$	29	12	2.36	4.3
—	2.9	—	—	$31\frac{1}{2}$	36	$16\frac{5}{8}$	23	1.56	5.0
0.2	3.8	−1.02	0.05	54	$59\frac{7}{8}$	$41\frac{1}{4}$	1080	4.00	7.4
4.0	5.0	0.49	2.22	$28\frac{3}{4}$	$31\frac{1}{4}$	$16\frac{7}{8}$	13	1.32	4.6
4.3	6.7	0.45	2.15	$25\frac{1}{2}$	$26\frac{7}{8}$	$18\frac{7}{8}$	12	2.20	8.6
4.9	—	1.20	—	$58\frac{7}{8}$	$59\frac{3}{4}$	$27\frac{3}{4}$	6	1.60	2.7
3.4	4.6	0.26	2.66	$25\frac{1}{8}$	$27\frac{1}{2}$	$15\frac{1}{2}$	9	1.20	4.8
7.3	8.7	0.10	2.67	$23\frac{3}{4}$	$28\frac{3}{8}$	17	9	1.44	6.1
6.9	8.1	0.94	3.84	$41\frac{7}{8}$	46	$23\frac{5}{8}$	11	0.80	1.9
5.8	5.2	1.24	4.50	$35\frac{3}{8}$	36	$18\frac{1}{8}$	8	1.50	4.2
4.1	5.1	1.08	5.82	$83\frac{1}{2}$	86	$45\frac{1}{2}$	14	2.80	3.4
1.8	5.0	0.16	1.00	$20\frac{1}{4}$	$30\frac{1}{4}$	$12\frac{5}{8}$	20	1.20	5.9
4.9	8.1	0.81	2.80	$38\frac{1}{8}$	$38\frac{1}{2}$	$23\frac{1}{2}$	14	2.60	6.8
2.1	3.0	0.79	2.84	$30\frac{1}{2}$	$30\frac{1}{2}$	$20\frac{5}{8}$	11	1.80	5.9
2.6	3.5	—	2.37	31	$34\frac{7}{8}$	$21\frac{1}{2}$	13	2.20	7.1
—	10.5	—	—	$19\frac{1}{2}$	$23\frac{1}{2}$	$14\frac{1}{4}$	13	1.08	5.5
11.1	19.0	0.30	1.19	$21\frac{1}{8}$	$23\frac{5}{8}$	$12\frac{1}{4}$	18	0.60	2.8
0.9	1.8	0.00	0.59	$18\frac{1}{2}$	$19\frac{7}{8}$	10	31	0.48	2.6
—	def	—	—	$14\frac{1}{8}$	15	$8\frac{5}{8}$	8	0.20	1.4
10.0	12.2	0.38	1.62	$30\frac{1}{8}$	34	18	19	1.12	3.7
—	12.5	—	—	$24\frac{1}{2}$	30	$17\frac{3}{8}$	14	1.04	4.2
—	7.2	—	—	$22\frac{1}{2}$	23	$14\frac{1}{2}$	10	1.60	7.1
2.6	4.1	0.44	1.87	$26\frac{1}{2}$	$26\frac{1}{2}$	$14\frac{1}{4}$	14	0.52	2.0
9.7	9.4	0.57	2.47	$30\frac{1}{2}$	$33\frac{3}{4}$	$19\frac{3}{4}$	12	1.00	3.3
—	10.0	—	—	$33\frac{5}{8}$	$36\frac{3}{4}$	$21\frac{5}{8}$	24	1.25	3.7
—	3.2	—	—	$14\frac{3}{8}$	$16\frac{1}{8}$	$9\frac{1}{4}$	8	0.56	3.9
1.8	3.5	0.35	1.14	$19\frac{7}{8}$	$22\frac{1}{4}$	$12\frac{1}{8}$	17	1.04	5.2
6.4	6.2	0.35	1.37	$34\frac{1}{4}$	$34\frac{1}{4}$	$18\frac{1}{8}$	25	0.56	1.6
6.2	6.8	0.15	0.63	$9\frac{3}{4}$	$13\frac{3}{8}$	6	15	0.24	2.5
—	8.6	—	—	$35\frac{1}{4}$	$40\frac{1}{4}$	$24\frac{7}{8}$	18	0.56	1.6
—	4.7	—	—	$20\frac{1}{4}$	$23\frac{5}{8}$	$15\frac{7}{8}$	8	0.80	4.0
4.6	3.4	0.04	0.93	$17\frac{3}{4}$	$18\frac{1}{8}$	$8\frac{5}{8}$	19	0.50	2.8
—	11.5	—	—	$12\frac{7}{8}$	$13\frac{3}{8}$	$8\frac{5}{8}$	88	0.72	5.6
4.0%	**5.5%**								
4.8%	**6.7%**								
4.1%	**5.5%**								

prior data meaningless. **l** Excludes \$9.5 million charge fourth-quarter 1982. **m** Excludes consolidated nonrecurring gain in fourth-quarter of \$6.0 million. **n** Excludes nonrecurring gains totaling \$41.3 million in fourth-quarter 1981. **o** Excludes \$1.9 million nonrecurring gain for 1982. **p** Excludes nonrecurring charges totaling \$38.6 million in fourth-quarter and \$16.9 million in full-year 1982 and loss of \$4.5 million in fourth-quarter 1981. **q** Excludes nonrecurring gain of \$2.1 million in fourth-quarter 1982, and charges totaling \$2.3 million in full-year 1982. **r** Excludes \$1.3 million nonrecurring gain in fourth-quarter 1982. **def** = deficit.

against other currencies and problems in the economies of many foreign countries cut heavily into exports of U.S. chemicals to overseas markets. As a result, exports of U.S. chemicals dropped 6.1% in 1982 from 1981 levels. In fourth-quarter 1982, exports were more than 11% below the level of the same period in 1981.

Lack of demand is evident in many other indicators of the chemical economy. For instance, capacity utilization in the U.S. chemical industry averaged less than 65% for most of the year. Employment was well off from 1981 levels. And the inventory-to-shipments ratio for chemicals averaged moderately high all year.

The only bit of good news was that many companies got a cost break as raw materials suppliers were unable to increase prices. For instance, Vincent L. Gregory, chairman of Rohm

Earnings declined at most chemical producing oil and gas companies

		FOURTH-QUARTER 1982						FULL-YEAR 1982		
	% chemical sales	Sales	Earnings	Change from 1981		Profit margin[a]		Sales	Earnings	Change from 1981
		($ millions)		Sales	Earnings	1982	1981	($ millions)		Sales
Exxon[b]	8%	$26,241.0	$1480.0	−12%	7%	5.6%	4.6%	$103,649.0	$4185.0	−10%
Mobil[c]	3	16,200.0	432.0	−11	−26	2.7	3.2	63,800.0	1530.0	−4
Texaco[d]	3	11,700.0	343.0	−20	−32	2.9	3.5	48,000.0	1421.0	−19
Standard Oil of California	3	—	—	—	—	—	—	—	—	—
Standard Oil (Ind.)[e]	10	7,500.0	415.0	−4	8	5.5	4.9	29,900.0	1880.0	−6
Gulf Oil[f]	8	8,160.0	321.0	3	5	3.9	3.9	30,658.0	1090.0	1
Atlantic Richfield	10	7,095.1	434.0	−1	−8	6.1	6.6	26,991.0	1676.0	−4
Shell Oil[g]	17	5,176.0	438.0	0	−4	8.5	8.8	20,214.0	1567.0	−7
Phillips Petroleum[h]	16	4,060.0	310.6	−1	67	7.7	4.6	15,890.0	801.9	−3
Sun Co.[i]	5	4,100.0	151.0	−9	1	3.7	10.0	16,300.0	537.0	0
Tenneco[j]	10	3,896.0	278.0	−8	10	7.1	6.0	14,979.0	840.0	−1
Standard Oil (Ohio)	4	3,216.7	463.9	−15	−3	14.4	12.7	13,529.2	1879.1	−4
Getty Oil	2	3,013.8	172.7	−13	−20	5.7	6.2	12,326.0	691.6	−7
Union Oil	11	2,736.1	225.1	−6	−5	8.2	8.1	10,900.0	804.0	−4
El Paso	15	—	—	—	—	—	—	—	—	—
Kerr-McGee	14	1,020.0	73.5	−5	11	7.2	6.2	3,780.0	209.8	−1
Internorth	10	—	—	—	—	—	—	—	—	—
American Petrofina	13	530.4	14.8	0	−13	2.8	3.2	2,253.7	54.4	−11

a After-tax earnings as percentage of sales. **b** Excludes nonrecurring $106 million charge in 1982. **c** Excludes nonrecurring $150 million in fourth-quarter 1982. **d** Excludes nonrecurring $37 million charge in fourth-quarter 1982 and $103 million in charges in prior quarters in 1982. **e** Excludes nonrecurring $54 million charge in 1982 and net nonrecurring gains of $57 million in 1981. **f** Excludes nonrecurring charge of $190 million in 1982 ($95 million of which in fourth quarter) and nonrecurring charge of $60 million in 1981 ($5 million of which in fourth quarter).

& Haas, says that lower raw material costs were a major contributor to fourth-quarter earnings, which were almost even with last year's after nonrecurring items had been excluded. Gregory says that worldwide raw material costs were 7% lower in the fourth quarter of 1982 than they were in the same quarter of 1981. In North America, raw material costs were 4% lower. At the same time, the company's selling price index was about equal to what it had been in fourth-quarter 1981.

Also, chemical companies have been streamlining their operations. The result has been the shedding of many unprofitable and marginal plants and the lowering of breakeven points in others.

However, these efforts have not been sufficient to save earnings in the fourth quarter. For 29 U.S. chemical companies that have reported fourth-quarter results so far, earnings were down 32.5% to $571 million from fourth-quarter 1981. And sales of these companies took their biggest fall of the year, dropping 9.0% from fourth-quarter 1981 to $16.8 billion.

As a result, profit margins (earnings as a percentage of sales) fell once again. In the fourth quarter, the average profit margin for the 29 chemical companies was 3.4%, compared with 4.6% a year earlier. Thus, profitability of the chemical industry in 1982 has been well below that in each of the corresponding 1981 quarters.

As in many past quarters, the smaller, more specialty-oriented chemical companies performed better, but only slightly better, than did the larger companies, many of which are dominated by commodity chemicals.

For the 18 larger companies that have reported thus far, combined quarterly earnings fell 32.7% from fourth-quarter 1981 to $510 million. Fourth-quarter sales for these companies dropped 9.1% to a total of $15.4 billion. Hence, profit margins for the larger companies fell to an average of 3.3% compared with 4.5% in the like period a year ago.

At 11 of the smaller companies, fourth-quarter earnings fell an average of 30% from a year earlier to $61.1 million. Their sales dropped 7.5% to $1.40 billion. Profit margins for the smaller companies slipped to 4.4% in the fourth quarter from 5.8% in the same quarter in 1981.

The fourth quarter merely capped the year for chemical companies. Earnings for the 29 companies for full-year 1982 dropped 33.2% to $2.86 billion from 1981. At the same time, combined sales fell 8.2% to $70.0 billion.

For the full year, earnings of the larger companies fell less than those of the smaller firms. Earnings for the 18 larger companies fell an average of 33.1% from 1981 to a combined $2.58 billion. Smaller companies' earnings fell an average of 34% to a combined $280 million.

Sales of the smaller firms, however, declined less than those at the larger firms. At the bigger firms, combined sales dropped 8.2% from 1981 to $64.1 billion. Smaller firms' sales fell 7.5% to $5.88 billion.

The smaller firms also continued to outperform the larger ones in profitability, although in both cases profit margins were falling fast. The average profit margin for the 18 larger firms in 1982 was 4.0%, compared with 5.5% for 1981. For the 11

FULL-YEAR 1981			STOCK MARKET DATA							
Change from 1981	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio Jan. 31	Annual indicated dividend	Dividend yield, % of price
						1982				
Earnings	1982	1981	4th qtr	1982	Jan. 31	High	Low			
−13%	4.0%	4.2%	$1.71	$4.82	$30⅛	$32¼	$24⅞	6	$3.00	10.0%
−37	2.4	3.5	1.06	3.67	26½	28⅝	19½	7	2.00	7.5
−39	3.0	3.9	1.32	5.46	32¼	34⅞	26	6	3.00	9.3
—	—	—	—	—	33⅛	37	23½	—	2.40	7.2
1	6.3	5.9	1.42	6.43	40⅜	49¾	33½	6	2.80	6.9
−16	3.6	4.2	1.83	6.03	29⅝	35¾	24¼	5	2.80	9.5
0	6.2	5.9	1.70	6.61	44⅛	50	32¼	7	2.40	5.4
−8	7.8	7.8	1.42	5.07	38	45½	27⅛	8	1.80	4.7
−9	5.1	5.4	2.03	5.25	32⅜	40⅛	23½	6	2.20	6.8
−16	3.3	6.6	1.24	4.40	31⅜	39¼	26¾	7	2.30	7.3
5	5.6	5.3	1.96	5.90	32⅜	36½	22⅞	6	2.72	8.4
−4	13.9	13.8	1.89	7.63	37¾	42¼	26½	5	2.60	6.9
−19	5.6	6.5	2.18	8.61	55¼	64⅞	41¼	6	2.60	4.7
2	7.4	7.0	1.30	4.63	30¼	37½	21¼	7	1.00	3.3
—	—	—	—	—	20¾	28⅛	13⅝	10	1.48	7.1
−1	5.6	5.5	1.39	3.98	29	38½	22½	7	1.10	3.8
—	—	—	—	—	26½	29¾	21	6	2.12	8.0
−27	2.4	2.9	1.37	5.03	55½	63⅜	41½	11	3.20	5.8

[g] Excludes nonrecurring $38 million gain in 1982. [h] Excludes nonrecurring charge totalling $156 million in fourth-quarter 1982. [i] Excludes nonrecurring gains of $733 million in fourth-quarter 1981. [j] Excludes nonrecurring gain of $10 million in fourth-quarter 1982 and net charge of $21 million for all of 1982 and nonrecurring gain of $6 million in fourth-quarter 1981 and $15 million for all of 1981.

Few oil companies made money in chemicals last year

There's no doubt that 1982 was an exceptionally bad year for oil and gas companies. The global oil glut and the lower oil and petroleum product prices that accompanied it made the decline in earnings registered by most U.S. energy firms nearly inevitable. But compared to those companies' chemical operations, the oil and gas results begin to look almost comforting.

It's not just that oil and gas company chemical earnings were off, it's that in most cases there were no earnings at all. Six leading U.S. oil firms providing after-tax data lost a total of $73 million on their chemical operations in 1982, after earning $497 million in 1981. But at least three of them—Exxon, Mobil, and Standard Oil (Ind.)—made some money over the course of the year. In the disastrous fourth quarter, only Exxon managed to record a profit.

The chief culprit, it comes as no surprise, was low prices, the consequence of depressed sales volumes and widespread overcapacity. At Exxon, for instance, where earnings fell 61% over the year and 55% in the fourth quarter, sales volumes dropped 10% in the U.S. and 6% abroad, chairman Clifton C. Garvin Jr. reports. The greatest sufferer remains Gulf Oil, which lost a whopping $229 million on chemical operations last year, $74 million of it in the fourth quarter alone. Most of those losses occurred in the U.S., where Gulf's chemical operations recorded a 1982 deficit of $164 million.

In fact, in a clear sign that the recession truly hit home last year, much of the oil industry's chemical losses took place in the U.S. Reporting its 1981 earnings, for example, Exxon noted that the main damage to chemical profits came from foreign operations. In 1982, by contrast, Exxon chemical earnings declined 26% abroad, but 89% in the U.S. Likewise, Texaco made $19 million abroad, but lost $27 million in the U.S.

There is little hope that after-tax statements of chemical earnings by other oil companies will brighten the picture when they are reported. In pretax statements for the fourth-quarter and full-year 1982, respectively, Atlantic Richfield reports chemical losses of $57 million and $96 million, and Standard Oil (Ohio) reports losses of $20 million and $23 million.

	AFTER-TAX EARNINGS					
	Fourth quarter			Full year		
$ Millions	1982	1981	% change	1982	1981	% change
Exxon	$ 20.0	$44.0	−55%	$ 92.0	$238.0	−61%
Gulf	−74.0	−33.0	def	−229.0	−34.0	def
Mobil	−12.0	23.0	def	21.0	93.0	−77
Shell Oil	−26.0	−11.0	def	−25.0	24.0	def
Standard Oil (Ind.)	−7.0	−9.0	def	76.0	101.0	−25
Texaco	−23.0	13.0	def	−8.0	75.0	def
TOTAL	$−122.0	$27.0	def	$ −73.0	$497.0	def

def = deficit.

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Earnings dropped sharply at many diversified chemical producers

	% chemical sales	FOURTH-QUARTER 1982 Sales ($ millions)	FOURTH-QUARTER 1982 Earnings ($ millions)	Change from 1981 Sales	Change from 1981 Earnings	Profit margin[a] 1982	Profit margin[a] 1981	FULL-YEAR 1982 Sales ($ millions)	FULL-YEAR 1982 Earnings ($ millions)	FULL-YEAR 1982 Change from 1981 Sales
Du Pont[b]	48%	$8368.0	$252.0	−1%	−30%	3.0%	4.3%	$33,331.0	$ 954.0	46%
General Electric	4	7460.0	524.0	−1	16	7.0	6.0	26,500.0	1817.0	−3
U.S. Steel[c]	10	4300.0	−363.0	31	def	def	6.6	18,907.0	−361.0	36
Procter & Gamble[d]	4	3030.0	203.0	5	11	6.7	6.3	12,304.0	823.0	5
Eastman Kodak	19	—	—	—	—	—	—	—	—	—
Dart & Kraft	11	2541.0	117.1	−4	909	4.7	0.5	9,974.4	350.3	−2
Beatrice Foods[e]	5	2313.9	82.0	3	3	3.5	3.6	9,154.0	311.6	2
Goodyear Tire & Rubber[f]	12	2087.1	49.8	−7	19	2.4	1.9	8,688.7	247.6	−5
3M[g]	15	1556.0	144.0	−1	−6	9.3	10.2	6,601.0	624.0	1
Georgia-Pacific	14	1366.0	−43.0	12	def	def	1.8	5,402.0	52.0	0
Aluminum Co. of America[h]	11	1057.1	−46.1	−3	def	def	3.0	4,647.6	−21.5	−7
Borden[i]	32	1086.0	42.7	2	1	3.9	4.0	4,111.3	137.9	−7
Pfizer	13	860.3	92.5	5	22	10.8	9.3	3,453.6	332.8	6
Martin Marietta	14	940.3	−2.4	9	def	def	4.5	3,526.5	91.6	7
Borg-Warner	24	804.5	48.3	2	−9	6.0	6.7	3,195.3	167.4	2
Esmark[j]	19	892.1	30.1	−2	39	3.4	2.4	3,389.1	92.7	0
Diamond Shamrock	34	755.3	46.2	−13	−23	6.1	6.8	3,200.0	149.5	−6
Merck	23	791.5	99.5	4	8	12.6	12.1	3,063.0	415.1	5
Kaiser Aluminum[k]	17	686.5	−95.3	−7	def	def	def	2,911.5	−86.9	−10
Eli Lilly	15	720.4	99.5	1	15	13.8	12.1	2,963.0	411.8	7
Engelhard[l]	11	602.4	17.2	10	−5	2.9	3.3	2,018.9	64.8	−8
General Tire & Rubber	19	—	—	—	—	—	—	—	—	—
NL Industries	22	415.5	1.7	−38	−98	0.4	14.2	2,213.5	188.8	−10
Koppers[m]	34	380.3	3.9	−22	−81	1.0	4.3	1,585.2	19.2	−17
Uniroyal[n]	26	470.0	−4.0	−16	def	def	2.7	1,967.0	11.0	−13
Northwest Industries[o]	6	389.3	6.6	−53	−93	1.7	10.7	2,306.6	184.6	−26
Upjohn	17	—	—	—	—	—	—	—	—	—
Emhart	16	401.0	24.0	−15	−8	6.0	5.5	1,710.0	80.0	−2
Tyler[p]	34	216.5	2.5	−6	−63	1.1	2.8	870.5	10.2	13
Vulcan Materials	37	169.1	8.1	−14	−55	4.8	9.1	719.4	54.7	−8

a After-tax earnings as percentage of sales. b Excludes nonrecurring $50 million charge in fourth-quarter 1982, nonrecurring net charge of $60 million for all of 1982, and nonrecurring charge of $33 million in fourth-quarter 1981. Results for 1981 reflect Conoco acquisition for only final five months of year. c Excludes nonrecurring charges of $153 million in fourth-quarter 1982 and $122 million for all of 1982 and nonrecurring gains of $40 million in fourth-quarter 1981; includes Marathon Oil results. d Excludes nonrecurring gains of $7 million in fourth-quarter 1982 and $10 million in fourth-quarter 1981. e Excludes nonrecurring $45 million gain in 1981. f Excludes nonrecurring gains of $17 million in 1982, $4 million in fourth-quarter 1981, and $16 million in 1981 overall. g Excludes nonrecurring $7 million gain in fourth-quarter 1982. h Excludes nonrecurring gains of $12 million in fourth-quarter 1982, $20 million earlier in

smaller chemical companies, profit margins in 1982 averaged 4.8%, compared with an average of 6.7% the year before.

Although many economists and security analysts are predicting a better time ahead in 1983, chemical company executives view this year from varying perspectives.

The most pessimistic among executives seems to be those at companies that produce fertilizers, partly because of new government programs that will limit acreage by paying farmers not to grow crops. Payment is made with crops that they are not raising.

International Minerals & Chemicals chairman Richard A. Lenon says, "While cost control efforts continue, the all important spring fertilizer season lies ahead with no encouraging price or volume indicators in sight." And Freeport-McMoRan says that the Administration's program may dampen by 15 to 20% phosphate applications during the spring season. However, with recent improvement in export demand and low producer and consumer inventories of phosphates, first-quarter 1983 fertilizer operating rates and related sulfur use likely will at least match 1982 levels.

A number of executives at both chemical and diversified companies plan to wait and see. At Diamond Shamrock, president and chief operating officer Allan J. Tomlinson says, "Significantly better performance in chemicals won't be possible without a general improvement in economic conditions." NL Industries expects its chemical operations to improve in conjunction with any strengthening of the worldwide economy. And Nalco Chemical president W. H. Clark Jr. says, "Although we expect our sales and earnings to improve as the year progresses, to date we have not received sustained signals that a significant upward trend has begun."

Perhaps Alfred T. Blomquist Jr., chairman and chief executive officer of Philip A. Hunt, sums up for this middle group: "We are approaching 1983 with a great deal of uncertainty about the world economy."

There are companies though, that

FULL-YEAR 1982			STOCK MARKET DATA							
Change from 1981	Profit margin[a]		Earnings per share		Stock price			Price-earnings ratio Jan. 31	Annual indicated dividend	Divided yield, % of price
						1932				
Earnings	1982	1981	Jan. 31	1982	Jan. 31	High	Low			
−34%	2.9%	6.3%	$1.05	$4.00	$ 40	$ 44⅜	$30	10	$2.40	6.0%
10	6.9	6.1	2.30	8.00	103½	100¾	58⅞	13	3.40	3.3
def	def	4.8	−3.75	−3.99	20⅝	26⅝	16	—	1.00	4.8
14	6.7	6.2	1.23	7.12	112½	123	78¼	16	4.20	3.7
—	—	—	—	—	85¼	98⅛	65⅜	—	3.00	3.5
1	3.5	3.4	2.14	6.40	66¼	72¼	48¼	10	3.60	5.4
−18	3.4	2.9	0.74	2.83	23⅜	25⅛	16⅞	8	1.50	6.4
2	2.9	2.7	0.67	3.35	33⅜	36⅞	18⅜	10	1.40	4.2
−7	9.5	10.3	1.36	5.31	75¼	81	48¾	14	3.20	4.3
−68	1.0	3.0	−0.42	0.48	24½	28	13¼	51	0.60	2.4
def	def	5.8	−0.61	−0.31	32⅞	35	21⅞	—	1.20	3.7
−14	3.4	3.6	1.47	4.67	51¾	53½	27¾	11	2.22	4.3
22	9.6	8.4	1.17	4.26	68½	80⅝	49⅞	16	2.32	3.4
−54	2.6	6.1	−0.11	2.92	42¼	47½	22¼	15	1.92	4.5
−3	5.2	5.5	1.10	3.90	41	44½	22	11	1.52	3.7
−1	2.7	2.8	1.99	5.85	56¾	60¾	31	10	1.84	3.2
−35	4.7	6.8	0.73	2.37	24	25⅝	16½	10	1.76	7.3
4	13.6	13.6	1.34	5.61	85¾	89	64	15	2.80	3.3
def	def	4.1	−2.20	−2.02	16⅝	18⅛	11½	—	0.60	3.6
10	13.9	13.5	1.31	5.42	62¾	65¼	45⅛	12	2.60	4.1
−10	3.2	3.3	0.64	2.41	33⅝	36⅞	18⅜	14	0.56	1.7
—	—	—	—	—	32⅝	35¼	17⅞	—	1.50	4.6
−40	8.5	12.8	0.01	2.90	17⅛	34¾	14¼	6	1.00	5.8
−64	1.2	2.8	0.06	0.42	17⅜	18¼	11¼	41	1.40	8.1
−84	0.6	3.0	−0.18	0.33	12½	13⅞	5⅞	38	—	—
−34	8.0	8.9	0.48	8.75	38	80½	32½	4	2.68	7.1
—	—	—	—	—	50¾	59⅜	38	—	2.28	4.5
7	4.7	4.3	1.95	6.53	48	49¾	27¾	7	2.60	5.4
−63	1.2	3.6	0.25	1.08	22	22¼	12⅛	20	0.60	2.7
−30	7.6	10.0	0.71	4.73	59⅞	64	38¾	13	2.44	4.1

1982, and $10 million in 1981. **i** Excludes nonrecurring $28 million gain in 1982. **j** Excludes nonrecurring gains totaling $15 million in fourth-quarter 1982 and net nonrecurring charge of $5 million in fourth-quarter 1981. **k** Excludes net nonrecurring gains of $28 million in fourth-quarter 1982. **l** Excludes nonrecurring $5 million charge in 1981. **m** Excludes nonrecurring charges of $53 million in fourth-quarter 1982, $50 million for all of 1982, $7 million in fourth-quarter 1981, and $1 million for all of 1981. **n** Excludes nonrecurring charges of $10 million in fourth-quarter 1982 and $15 million in fourth-quarter 1981 and net gain of $15 million in 1982 overall. **o** Excludes nonrecurring gain of $141 million in 1981. **p** Excludes nonrecurring $5 million gain in 1981. **def** = deficit.

see increasing and perhaps definite signs of economic improvement. For instance, Olin chairman John M. Henake says, "We believe the low point of the recession was reached in the November-December period. There are signs that economic activity in our basic businesses is starting to improve. We expect continuing but modest improvement as the year progresses. But starting at a business level significantly lower than that of January 1982, it will take some time before year-to-year comparisons become favorable." Rohm & Haas' Gregory is very specific. "The company's plans for 1983 assume slow economic growth, modest increases in feedstock costs, and a continuation of current inflation rates."

Monsanto chairman John W. Hanley says, "As 1983 begins, we see several improving economic signals, including lower interest rates, a measurable upturn in single family housing starts, and predictions of substantially increased U.S. auto production in the first quarter. However, we still anticipate modest economic growth in 1983, although less than that which normally follows a recession.

A number of companies in quarterly statements commented on the overseas markets. At H. B. Fuller, president Anthony L. Andersen stated that Latin American results reflect the continued effect of the strong U.S. dollar relative to local currencies, causing a decline in both sales and net earnings for the year. However, he did note significant improvement in the company's operations in Brazil and Argentina.

Petrolite, a producer of oil field chemicals, felt the effects of the current oil glut. Petrolite says that foreign oil field sales were flat for the quarter as weakened demand among major oil producers offset gains in other areas.

And at Loctite, chairman and chief executive officer Robert H. Krieble says that although sales to U.S. automotive repair and consumer markets were up sharply, they were not sufficient to offset continued weakness in industrial markets both in the U.S. and abroad nor the effect of the stronger U.S. dollar. □

Reinforced plastics producers predict recovery

Like many other forecasters, producers of reinforced plastics were predicting reasonably good growth for their products at this time last year. And like most other forecasters, they were wrong. Shipments of reinforced plastics plunged 17% in 1982, a drop almost as severe as that registered in 1980, another disastrous year. This year, producers expect sales volume to increase 8.4% over 1982, a rate of growth that will be welcome but will leave the total far below the 2 billion lb level topped in 1978 and in 1979, the industry's record year.

These forecasts, the result of a yearly survey of producers and others in the industry, were reported in Houston last week to the annual meeting of the Reinforced Plastics/Composites Institute of the Society of the Plastics Industry. The survey is part of a report prepared for the group each year by Laura Morrison of the public relations firm Morrison/Gottlieb of New York City.

The industry's confident outlook for 1983 is based partly on expectations of a recovery in the general economy. The recession gets almost all of the producers' blame for last year's decline. "Since we provide materials and molded products to almost every major industry, when they take a dive, we go down too," says Frank W. Como, a marketing division vice president for Owens-Corning Fiberglas and chairman of the institute. "Actually, our materials traditionally hold up better than the markets they serve. As a result, in a growth year—like 1983—we go up faster."

There were no bright spots in 1982. Shipments to the land transportation sector, which accounts for 24% of the reinforced plastics industry in poundage, were down 19.3%. The drop is attributable to the poor performance of the automobile industry, where production fell 16%. In 1983, transportation equipment output is expected to rise. As a result, producers of reinforced plastics project a 12% increase in shipments to the land transportation sector. Still, even that gain would leave the total for the year, at 402 million lb, 27% below the 550 million lb sold during the peak year of 1979.

Sales in the construction sector, whose 1.6% decline in 1982 was the smallest drop for any individual market segment last year, will grow 5.8% in 1983, the institute says. That will be just enough to make growth for the sector over the five-year 1978–83 period positive, although the 1983 total of 330 million lb will fall slightly short of the peak reached in 1979.

The anticorrosion sector, the only market in which consumption of reinforced plastics grew between 1978 and 1982, accounted for 14.5% fewer sales last year than in 1981. With an anticipated rebound of 7.2% this year, however, its annual total will rise to 252 million lb, the highest since 1981, the best year ever for the sector.

Only a small recovery is seen for the marine sector, however, which was the second largest consumer of reinforced plastics in 1978. Depending largely on commerce in small recreational boats, the sector has been particularly damaged by the ups and downs of the business cycle since the late 1970s. Sales of reinforced plastics to the marine industry were down 20.7% in 1982, and the institute forecasts growth this year of only 2.2%. At that rate, the sector's consumption for the 1978–83 period will have fallen 11.4% per year.

Reinforced plastics demand in 1983 still trails 1979 levels

Millions of lb	1983[a]	1982[a]	1981	1980	1979	1978	% change 1982–83[a]	% change 1981–82[a]	Average annual change 1978–83[a]
Transportation, land	402	359	445	416	550	535	12.0%	−19.3%	−5.6%
Marine	235	230	290	275	385	430	2.2	−20.7	−11.4
Construction	330	312	317	287	335	320	5.8	−1.6	0.6
Anticorrosion	252	235	275	252	238	216	7.2	−14.5	3.1
Electrical	161	140	178	162	190	170	15.0	−21.3	−1.1
Appliance	84	82	117	104	130	123	2.4	−29.9	−7.3
Consumer goods	97	84	115	103	126	116	15.5	−27.0	−3.5
Aircraft	25	22	28	25	23	22	13.6	−21.4	2.6
Other	70	64	75	70	79	74	9.4	−14.7	0.3
TOTAL	**1656**	**1528**	**1840**	**1694**	**2056**	**2008**	**8.4%**	**−17.0%**	**−3.8%**

a Estimates. **Source:** Reinforced Plastics/Composites Institute of the Society of the Plastics Industry

For all this dismal performance by the major outlets for reinforced plastics in 1982, the biggest percentage drops came in the minor markets. Shipments to the electrical sector fell 21.3% last year, but much of that lost ground will be regained with a 15% increase in 1983, producers predict. Similarly, sales to the consumer goods sector plunged 27% in 1982. If the institute's forecasts are correct, poundage will grow 15.5% this year. In neither case, however, will next year's growth be enough to return sales totals to the levels attained in 1978.

The appliance sector, which had been larger than the consumer goods market until last year, dropped 29.9%, the biggest decrease by any market for reinforced plastics. And the outlook for 1983 is only mildly encouraging: Producers see a rise in shipments of only 2.4%. That would mean an average annual drop of 7.3% in sales to appliance makers for the 1978–83 period.

Aircraft manufacturers, whose own production levels fell 7.4% last year, ordered 21.4% less reinforced plastic in 1982 than in 1981. Although an anticipated increase of 13.6% this year will give sales to the sector a positive growth rate for the five-year period, at 25 million lb, it will remain a minor part of the industry.

Shipments in the miscellaneous category declined 14.7% in 1982. This year, producers predict, sales will increase 9.4% to 70 million lb.

Compared to all reinforced plastics last year, reinforced thermoplastics were relatively healthier. Shipments fell just 11.7%, compared to 17% for the industry as a whole. That made the reinforced thermoplastic share of all reinforced plastic poundage roughly 15.4%, a share which it is expected to maintain in 1983. □

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Archaeological Chemistry

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Cover: Model of a male skeleton with burial goods from about 1500 BC, found in Thailand. Photo courtesy University Museum, Philadelphia

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Rayon Aims for Specialty Niches in Low-Growth Market

Rayon still will have a struggle in U.S. and Europe, but may find growth in larger markets in East bloc and developing countries

Patricia L. Layman, C&EN London

Earlier this year, a woman in a European clothing shop was admiring a dress that had caught her fancy, and upon protesting a too-high price, was told, "Yes, madam, but it is real rayon."

That is hardly the commonest occurrence these days, of course. But that it happened at all is one indication that the fortunes of the oldest man-made fiber may be changing. From its beginnings as an artificial silk, rayon frequently has been regarded as shoddy, at the worst, or unglamorous, at best. The shoddy image was intensified during World War II, when general shortages of silk and cotton led to its wide use. Some of the applications were ill suited, and the resulting products did not perform well.

Rayon also suffers from being an "old" technology, and over the past several decades, it has seen its markets steadily and speedily slip away to upstart synthetic fibers, petrochemical-based polyester, nylon, acrylic, polypropylene.

From a market that hit its peak in the 1950s and early 1960s, rayon has settled into a holding pattern worldwide. During the past decade, global production fell about 7% to 3.45 million metric tons in 1982, according to the best estimates from companies, the International Rayon & Synthetic Fibres Committee (Paris), and the Textile Economics Bureau (New York City).

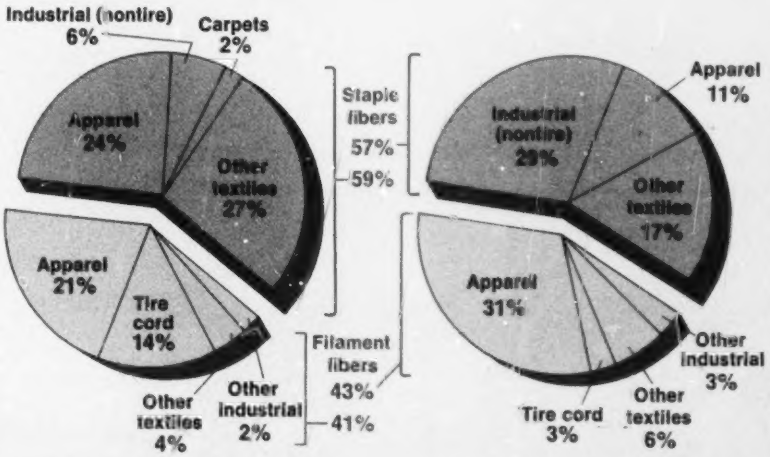
But market erosion may have stopped. Worldwide output in recessionary 1982 was scarcely changed from 1981. For the future, industry sources expect a somewhat split growth pattern regionally. In Europe and the U.S., where rayon has lost ground in recent decades, the outlook is flat at best. However, in the East bloc and developing countries, where rayon has much greater volume, use of the fiber still may grow a few per cent per year. Worldwide, sources expect 1 to 2% annual growth for rayon in coming years.

Growth probably will favor the staple (chopped) type of rayon, which already makes up 70% of worldwide output. This will be especially true if rayon use grows in apparel and other blends with polyester and cotton.

The earliest rayon chemistry goes back to 1883, to the English chemist Sir Joseph Wilson Swan and the French researcher Count Hilaire Bernigaud de Chardonnet. Swan was seeking replacement for silk filaments for the new electric lamp. Chardonnet, however, was interested in producing artificial silk textiles, which he described in his 1883 patent. The chemistry proceeded by way of nitrocellulose, not a particularly pleasant material. And, indeed, rayon historians point out that many of the early experiments, and some early factories, came "to an explosive end." Other researchers, still seeking an artificial silk for electric-lamp filaments, continued the R&D, and in 1891, the cuprammonium process got its start in Germany. Closer to the end of the century, it was adapted to produce an artificial silk fiber for textiles, called glanzstoff.

On paper, the relatively straightforward cuprammonium process has

Staple fibers fill more than half of rayon demand in both Europe and the U.S.



Total 1982 European demand = 410,000 metric tons

Total 1982 U.S. demand = 325,000 metric tons

Source: International Rayon & Synthetic Fibres Committee; Textile Economics Bureau

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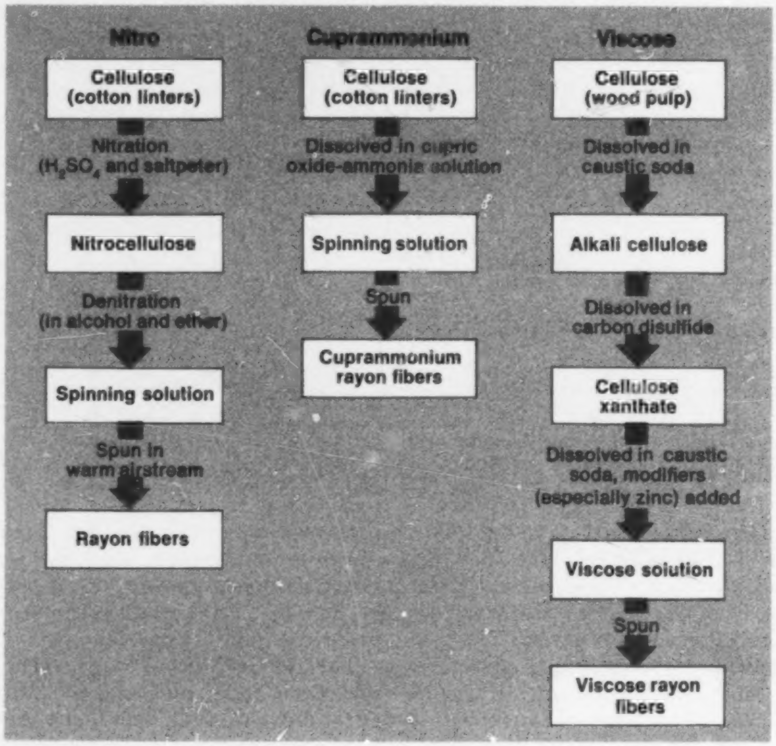
Hazards of nitro process led to adoption of cuprammonium process, but viscose versatility finally proved most popular


Nitro
Cellulose (cotton linters)
Nitration (H_2SO_4 and saltpeter)
Nitrocellulose
Denitration (in alcohol and ether)
Spinning solution
Spun in warm airstream
Rayon fibers
Cuprammonium
Cellulose (cotton linters)
Dissolved in cupric oxide-ammonia solution
Spinning solution
Spun
Cuprammonium rayon fibers
Viscose
Cellulose (wood pulp)
Dissolved in caustic soda
Alkali cellulose
Dissolved in carbon disulfide
Cellulose xanthate
Dissolved in caustic soda, modifiers (especially zinc) added
Viscose solution
Spun
Viscose rayon fibers

a lot going for it. But copper is expensive and difficult to recycle, which throws off the economics of the process. Only a very little cuprammonium rayon is still made, even though the fibers themselves can produce luxurious, lustrous textiles probably the closest to silk that are obtainable with rayon.

Viscose process for making rayon is a more complex chemistry. But, even though it is "a damned nuisance," as one rayon chemist puts it, because it is so complex, it is versatile enough that a manufacturer "can still play tunes on the chemistry." It got its commercial start with Courtaulds in the U.K., when the company in 1904 bought the British rights (and subsequently the U.S. rights) to the patents of 1892 and 1898 of chemist Charles F. Cross, researcher Charles H. Stearn, and glassblower Charles F. Topham, all of the U.K. Cross's master patent of 1892 covered the viscose process; the Stearn patent of 1898 covered the production of filaments from viscose; Topham's various patents described mechanical devices for processing and spinning the viscose rayon fibers into yarn.

Rayon makers have had to work out a few problems along the way. Primary among them have been environmental considerations, to handle the problems associated with the viscose process. Cleanup costs have been considerable. Enka, Akzo's fibers unit, for example, estimates that the cost of installing cleanup equipment at its Arnhem, Netherlands, plant was $10 million, with subsequent annual costs of $2 million. Similarly, Avtex spent $12 million on an air-emissions control unit at its Front Royal, Va., plant, besides working out a water treatment system that, it now boasts, sends out water cleaner than it comes into the plant. Producers have those costs under their belt now, so they don't have much present impact on the manufacturing costs of rayon, or subsequent selling prices.

Those prices are competitive with prices for polyester, marketers now insist. That is a far cry from the early 1970s, however, when oil was $2.50 a barrel, and seemed as if it would remain there forever. That meant that both the polyester raw materials and its energy processing costs were low. And abundant overcapacity ensured that the price was low. Compound that with the hefty environmental control outlays facing rayon makers at that time, and the overcapacity for the fiber, and it's no wonder a few companies wanted out.

FMC Corp., for one, wanted to sell off its American Viscose operations. It probably was ready to close the operation down completely had not the unit's management put together an employee buy-out, forming Avtex. As another example, American Cyanamid closed down its rayon production.

And even those companies that stayed in the business have had to take a long—and realistic—look at the future of the fiber, to decide how much research and development support to give it. Avtex and Courtaulds are concentrating R&D on their now modified rayon fibers, and are into market development for still relatively untapped industrial-fibers markets.

Enka earlier was spending significant amounts of R&D time and money on a new solvent-extraction process, to get away from the complex viscose chemistry. But the most promising solvent was an amine oxide, and that put the work on the back burner. Amine oxides feature a typical fragment amine aroma, so they must be completely recovered—just as manufacturers now have to do with carbon disulfide and its breakdown products. But more important, the amine oxide wasn't available commercially. Had Enka adopted a process based on it, the company would have had to build an amine oxide plant, or arranged with another company to build one for merchant supply. It all would have cost even more than a new viscose plant, Enka concluded—for a process that could not really obtain the performance versatility of the viscose process.

It hasn't helped such development decisions that some of rayon's old stalwart markets have been hurt. Here, however, there are regional differences. From its predominance

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Production of cellulosic fibers has risen in East bloc and Asia over past decade

Thousands of metric tons	U.S.	Non-U.S. Americas[a]	Western Europe	East bloc[b]	Asia[c]
1971	718	166	1092	879	712
1972	728	172	1085	960	756
1973	731	179	1121	1011	790
1974	668	166	1045	1064	779
1975	470	142	769	1083	698
1976	518	141	884	1115	770
1977	547	145	950	1062	813
1978	560	142	948	1065	851
1979	588	152	963	1047	880
1980	551	147	871	1068	877
1981	539	135	826	1036	927
1982[d]	525	130	810	1050	930

a Argentine, Brazil, Canada, Chile, Colombia, Cuba, Mexico, Peru, Uruguay, and Venezuela. b Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Romania, U.S.S.R., and Yugoslavia. c Bangladesh, China, India, Iraq, Japan, Pakistan, South Korea, Taiwan, and Thailand. d Estimates. **Note:** Includes acetate textile fibers (about 5 to 7% of total, but excludes acetate tow for cigarette fibers. **Sources:** International Rayon & Synthetic Fibres Committee (Paris); Textile Economics Bureau.

as a tire cord in the U.S. in the 1950s, for example (C&EN, July 26, 1982, page 13), rayon now has only about 2 to 3% of the U.S. tire-cord business, a percentage identical to that held in Japan. In the developing countries, rayon holds 25% of the tire-cord market. But in Western Europe, it is the largest man-made tire fiber, holding a fat 21% of the tire-cord market. It is second only to steel, which—because of its heavier weight—holds a 69% share, thanks to radial tires having 95% of the passenger-car tire market. In fact, rayon is the carcass reinforcement cord for up to 80% of passenger-car tires in Europe.

The developing nations have been the scene of some dramatic rayon expansion. Among the reasons are the requirement in warm countries for comfortable fibers, with comfort being one of rayon's best characteristics, and the natural-resource base that many countries possess.

A domestic source of raw materials, too—cellulose from wood pulp—is not necessarily all it takes. The Enka tire-cord plants in Europe, for example, get their wood pulp from U.S. southern pine forests, rather than Scandinavia's northwoods timber; so do the rayon tire-cord plants in India. Courtaulds' textile-fibers plant in Cornwall, Ont., Canada, and in Mobile, Ala., get their wood pulp from Courtaulds' subsidiary in South Africa. Moreover, conservationists are concerned that developing countries' forests are being stripped, altering the ecology of an area, with no reforestation programs under way.

The natural-resource aspect of rayon eventually must become more attractive. However, eventually may take some time. Many rayon marketers are prepared for petrochemical-based synthetics to make inroads on rayon even in developing countries, although perhaps not to the same extent that synthetics have in Western Europe, Japan, and the U.S. They also expect such developing countries to continue to concentrate on apparel and textile production, which can provide employment with low labor costs, particularly with government subsidization. And even though recent capacity buildup has been in the East bloc and in the developing countries of Asia, some Western rayon producers believe that there are indications that those countries are beginning to take steps to adjust capacity to reflect consumption.

For now, worldwide rayon capacity is adequate, but not ample. In Western Europe, for example, filament-yarn production has been running at about 90% since a shutdown in 1980 of roughly 10,000 metric-tons-per-year capacity. In the U.S., the utilization rate is somewhat lower, probably slightly less than 80%. As rayon producers point out, that's still quite a bit better than most other man-made fibers these days. But they argue that, given the generally stable consumption outlook for rayon, there is little economic justification for more rayon plants in the future.

Other European producers, for example, are nettled by the recent announcement by rayon producer Snia Fibre, in Italy, that it will build new rayon facilities with an initial capacity of 6000 metric tons per year of rayon filament. Nearly all of the investment will come from the Italian government, and other rayon producers see that as subvening the existing European agreements on fiber production.

Producers of rayon filament are particularly upset because the proposed Snia addition would be bound for the largest rayon-filament market—in linings. Linings presently make up more than half of Western Europe's rayon-filament textile consumption of about 40,000 metric tons per year.

In one effort to lessen dependence on such specific markets as linings, Western rayon producers are adopting "engineering" as their password, as they seek specific market niches for their fibers. They clearly have lost the battle for commodity fiber markets throughout the world, so their marketing approaches now reflect that fact. Specific demands—from the mundane world of nonwoven diaper covers to carbonized rayon used as an ablative covering for space shuttles, hollow fibers to give extra warmth and fullness for blending into thermal fabrics, extra-absorbent fibers for medical and hygienic products—all these are part of the new effort.

In the U.S., the Rayon Council holds seminars and programs to kindle the interest of young chemistry and textile engineering students in what has long been considered a humdrum, old-auntie fiber. And producers try to steer their customers into using the fibers in suitable applications, away from unsuitable end-uses. Those unsuitable applications led in the 1930s and 1940s to the image that rayon is finally starting to live down, as specially selected end-uses boost it in its uphill battle to be respected as "real rayon." □

Industry support of academic research growing

The widespread belief that a significant deterioration occurred in university/industry relationships during the 1960s and 1970s is more myth than reality, according to the National Science Board's fourteenth annual report to Congress. "There are many indications that such relationships remained both vigorous and varied," the report says.

Further, corporate support of academic research is significantly higher than generally believed, according to the report. It is true that during the early 1960s industrial support stayed flat at about the same constant-dollar level. But since 1965, constant-dollar support for university R&D from industries has doubled.

The report also takes issue with the oft-cited base figure of between 3% and 4% for industry support of total academic R&D. For a more complete picture, it says a number of omissions need to be added to the database. Among these omissions, the report says, are major research universities that do not report R&D expenditures from industrial sources. Industrial gifts and loans of scientific equipment are rarely included in the database. Also, many universities do not count as industrial support gifts for research from corporate-sponsored foundations. And many universities do not estimate the portion of unrestricted corporate gifts for operating and capital funds that eventually are spent on research facilities, equipment, and faculty and student fellowships.

If all of these omissions are taken into account, the report says, it is not unreasonable to estimate that the current corporate contribution to total academic R&D is in the neighborhood of 6 to 7%. This represented a sum between $400 million and $450 million in 1980–81. As support for this estimate, the report points to a 1981 survey of all departments listed in the American Chemical Society's Directory of Graduate Research, which showed that 7% of extramural research support for chemistry departments and 23% for chemical engineering departments came from industry.

If these current levels of corporate contracting and philanthropy for academic research are maintained through the current business recession, more reinforcement will be provided for already "sound reasons to believe that we may be at the threshold of a permanent new state of corporate-academic research relationships," the report states.

One of the major reasons for believing that the number of university/industry relationships can only increase is that problems and opportunities in today's technologically based industrial production are substantially different from those of the past. For example, the report points out that product and process improvement and innovation in some industries have evolved to levels of complexity that demand understanding of fundamental physical and biological phenomena. Hence, these corporate activities require much higher levels of training in and use of basic science and engineering than the "cut and try" inventor of yore had. In addition, incremental advances in narrowly focused technical areas, characteristic of much industrial development in the past, are giving way to the use of a broad range of science and engineering disciplines on complex, often ill-defined problems, or exploitation of new analytical capabilities. Hence, it is becoming increasingly difficult for one industrial laboratory to encompass the requisite expertise.

Therefore, industry will be looking to universities for solutions to very specific scientific problems in which the university has special expertise. This in turn will lead to broader relationships. A field study done for the report found that the initial impulse in the majority of university/industry relationships sampled came from the university, with a significant portion of the academic researchers pursuing these relationships having had prior consulting or other employment relationships with companies. Thus, the report says, "We have a multistage series of relationships: Company wants technical/scientific advice (general or specific) and seeks out a professor; professor/consultant sees opportunities for research and initiates research relationship; company tracks and (maybe) utilizes the research and makes employment offers to the bright graduate students and postdoctorals working on the project; and the cycle is repeated in future years."

However, the report cautions that the focus on research interactions should not obscure the primary interest of research managers in making research connections with universities: manpower acquisition. Recruitment at the leading edge of science and engineering is a highly competitive process; thus it is reasonable to suppose, the report says, that some significant portion of the current upswing in industrial support of academic research is directly related to manpower concerns. □

Most industry support for university research departments goes for specific projects

Type of support	Chemistry		Chemical engineering	
	$ Thousands	%	$ Thousands	%
Grants or contracts for specific research projects in response to explicit proposals	$ 5,516	54%	$ 4,477	44%
Gifts or grants to specific faculty members or for specific research areas	2,469	24	1,845	18
Uncommitted gifts or grants to university departments	1,910	19	3,139	31
Membership fees from industrial associate programs	260	3	564	6
Other	59	<1	157	1
TOTAL INDUSTRIAL SUPPORT	$ 10,214		$10,182	
Total extramural support	$145,672		$44,338	
Industrial funds as % of extramural funds	7%		23%	

Note: 72% or 136 of the chemical departments surveyed responded, as did 81% or 79 of the chemical engineering departments.

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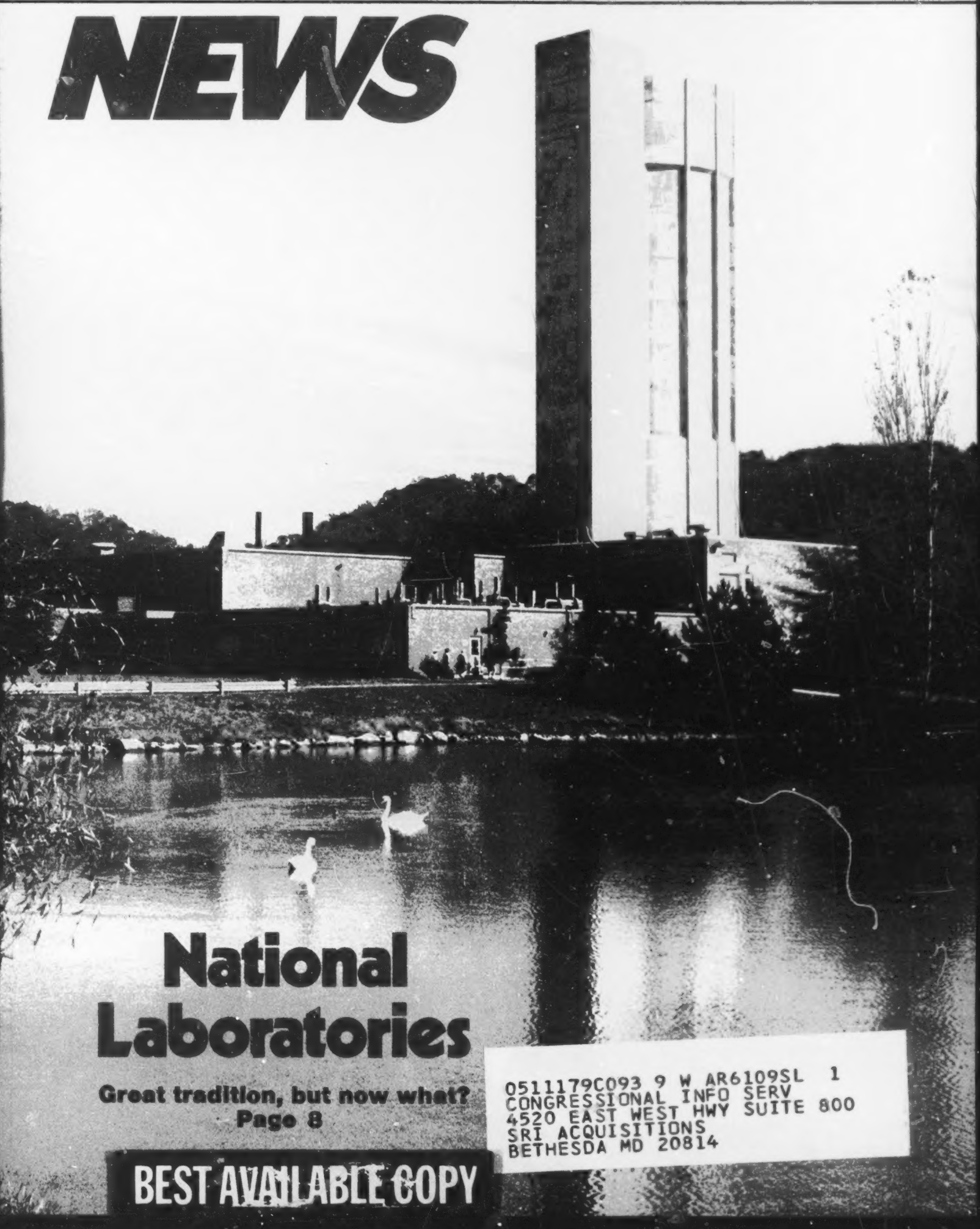
FEBRUARY 28, 1983

CHEMICAL & ENGINEERING NEWS



National Laboratories

Great tradition, but now what?
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Cover: Holifield heavy ion research facility at Oak Ridge National Laboratory, Tennessee

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News Focus

National laboratories, bastions of weapons development and industrial innovation, face reassessment of their reason to be. Page 8

Tradition-Rich National Labs Brace for Change

Weapons development, industrial innovation are now deemed sole priorities of labs; some question whether new policies ignore long-term energy problems

Wil Lepkowski, C&EN Washington

A little more than 40 years ago, the U.S. decided to build a revolutionary kind of bomb based on the power within the atom's nucleus. Thousands of construction workers, engineers, and scientists were recruited, and in three cities that were kept secret—Hanford, Wash., Oak Ridge, Tenn., and Los Alamos, N.M.—the work of making plutonium, separating uranium-235 from U-238, and building the bombs themselves began. By 1945 three "devices" were exploded, and the world knows the rest of that story.

Off of those three centers, and the Radiation Laboratory at the University of California, Berkeley, sprouted a group of eight large national atomic energy laboratories that marked the new "big science" era in government science and technology. The aims were to build ever-new types of bombs and missile warheads, tame the atom for peaceful uses, and to investigate the deeper secrets of the atomic nucleus. The dreams were heady and eventually reality took over.

Atoms for war meant a very precarious kind of security. Atoms for peace turned out to be more expensive and controversial than anyone thought in the beginning. The labs developed the light-water reactor, dropped other designs, and in retrospect failed to foresee and warn against serious safety and waste disposal complications that plague the nuclear industry today. As the environmental quality movement grew and flourished and the oil shock of 1973 shattered U.S. security over energy supply, the laboratories began showing a confusing and diverse image. Under the old Atomic Energy Commission these labs were fountains of new ideas and autonomous keystones of science and policy. But when the Department of Energy took over in 1976, their images became blurred and confused. Universities and government-supported research firms saw them more and more as competition for the scarce federal dollar, and the political sharks were sent out to dismember them.

More than a year ago, White House Science Adviser George A. Keyworth II sent chills through the laboratory community when he said publicly that it was doing a lot of unneeded research, especially in such areas as energy conservation, fossil fuel studies, and renewable energy sources. Keyworth said it should be directed to working on problems fundamental to industry. He feels that way even more today and points to the recently announced Center for Advanced Materials at the Lawrence Berkeley Laboratory as the emerging model. Materials scientists at universities are skeptical of the model and resent not being consulted while the center was being planned. But Keyworth and LBL director David A. Shirley are enthusiastic about the initiative, and the Administration is asking for $192 million to start work on the new center, built around the lab's synchrotron light source.

So the future of the national labs is not really at stake anymore, but it does remain clouded. The Administration wants to abolish the Energy Department and move the labs to the Department of Commerce. Science Adviser Keyworth is causing shivers in the labs by challenging them to come up with programs as novel as Berkeley's materials center. Programs in fossil fuel research and soft energy innovations, begun with such enthusiasm during the Carter Administration, have kneeled before the budgetary axeman.

Brookhaven and Argonne for a while were fearing for their existence. Over the past two years, Oak Ridge has laid off 570 people, Lawrence Berkeley 640, Argonne 840. High-energy physicists at the labs are embroiled in a vicious debate over whether to stop work on Brookhaven's partially built Isabelle accelerator and start a new-generation machine someplace in the Southwest. Thus, the labs always have been centers of debate and probably always will be. All of which isn't bad. Three high-level panels have been assessing their nonmilitary work during the past year and their reports are beginning to come out.

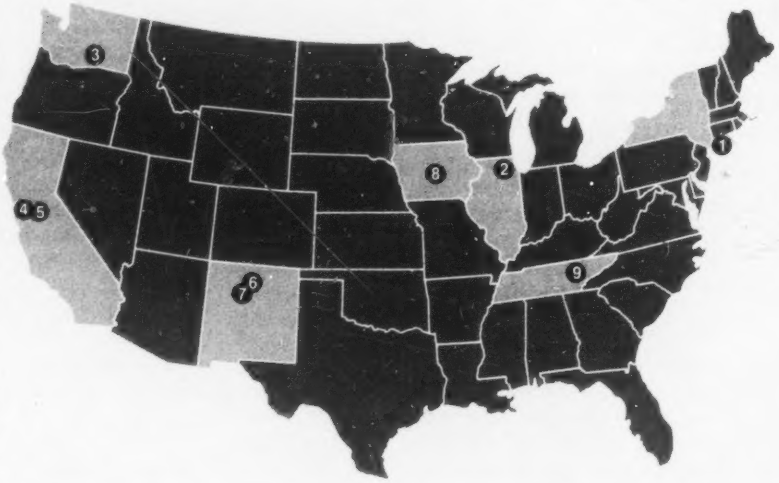
"A lot of people in the labs are shell-shocked by all

National labs network focuses on big physics, weapons research

3. PACIFIC NORTHWEST
Founded in 1942 solely to produce plutonium in reactors for Manhattan Project. Experienced downturn in 1964 when plutonium production all but ceased. Battelle Memorial Institute took over and under special contract integrated its work with that of Atomic Energy Commission research at site. Chief current strengths are nuclear waste disposal, breeder reactor development. No significant ties with universities but a model of sorts in integrating a lab with a regional economy. Run by Battelle

2. ARGONNE
Founded in 1946. Mainly reactor development; focus on breeder and other fission reactors. Basic research focus on general materials studies. Origin in University of Chicago metallurgical laboratory where in 1941 first chain reaction was demonstrated. Run by University of Chicago

1. BROOKHAVEN
Established in 1947 as East Coast center for high-energy physics research. Has other radiation-generating instruments for studying basic properties of materials. Strength is relations with universities in their use of big instruments. Operated by Associated Universities Inc.



4. LAWRENCE BERKELEY
Formed in 1943, lab is grandfather of national laboratories with origin in University of California, Berkeley, radiation laboratory where first cyclotrons were built. Considered to be model of national lab integrated with university. Now multipurpose lab stressing basic research that, in tradition of charismatic founder Ernest O. Lawrence (founder of Big Science), is seen as model of the power of physics and chemistry to help solve any problem. Run by University of California

5. LAWRENCE LIVERMORE
Weapons primarily, with significant effort (20%) going into magnetic and laser fusion energy. Founded in 1952 under influence of Edward Teller who wanted separate laboratory to compete with Los Alamos in weapons development. Operated by University of California

7. SANDIA
Formed in 1945, mainly engineering for weapons development. Was devoted totally to weapons work until 1973 when it began diversifying into solar, fossil fuel, conservation, and nuclear energy development work. Operated by Western Electric

9. OAK RIDGE
Origin in University of Chicago metallurgical laboratory and founded in 1942 as Clinton Laboratory to serve as lab for magnetic and gaseous diffusion separation of uranium-235 from U-238. Most diversified of all labs with strong points in environmental sciences and biology (now both declining), and fission and fusion energy development. Like Lawrence Berkeley, has rich tradition in academic relationships though without immediate proximity with university. Now undergoing change in contractors (currently operated by Union Carbide nuclear division)

6. LOS ALAMOS
Birthplace of atomic bomb, continuing as primarily weapons laboratory with strong component in medium energy physics. Established in 1943 and run by the University of California

8. AMES
Founded in 1946, lab produced uranium for first chain reaction at Chicago. Research on ultra-high purity metals. At $15 million budget, smallest of labs. Operated by Iowa State University

these investigations," comments Joel Snow, director of science and technology affairs of DOE's Office of Energy Research. "But maybe there will come out of all this a new appreciation for these labs for their place in the total system." What has been decided is that they are indeed important, even unique, technical resources that the country ought not to squander. But they are still felt to be victims of bureaucratic bungling and misdirection.

When the Atomic Energy Commission gave way to the Energy Research & Development Administration, and two years later to the Department of Energy, broad-scale funding ended and the labs had to begin seeking smaller contracts in various, often unconnected fields. Contract administration came under the different DOE operations offices with the result that scientists had to deal with contract officers in both Washington and the regional operations offices.

"My concern," says Los Alamos director Donald M. Kerr Jr., "is if we allow lower tier government people to make decisions about the labs, it could result in less opportunity to use our technology to solve problems. We have 600 individual programs here, and that means there are 600 people in Washington who think they own a piece of the lab."

So the labs are currently being roundly assessed. But to Oak Ridge director Herman Postma, the assessments are at least helping to give high-level skeptics a sense of what the labs do offer the country. "One of the panels

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ERAB report criticizes Energy Department management of labs

The report issued late last year by the Energy Research Advisory Board, although only moderate in its praise of the laboratories, did urge that they have served as important centers of research on national problems. What the panel is critical of, however, is the floundering system of support, management, and oversight by the Department of Energy.

DOE's management practices regarding the laboratories, it states, "are not consistent with their long-range future well-being and deny to the nation the full benefits of this national research and development asset." It goes on to say that although the Reagan Administration wants to decrease the types of federal R&D programs that private industry can do, there are potential innovations that industry will not work on. It says the laboratories could fill a legitimate slot in the national R&D picture with industry and the universities.

The question, of course, is how to achieve this systematic sleight of hand with DOE's reluctance to establish any overall management information principles. This is the summary of the report's findings and recommendations:

Direct functions. The laboratories should keep doing what they do best: research in high-energy and nuclear physics, nuclear medicine, generic energy research, and fields of research such as ecology and radiobiology that some of the laboratories established to study the effects of radiation. Universities and industry should increase their participation in that activity.

Support functions. The laboratories act as agents to manage both complex projects and work they contract out to industry and universities. They give technical assistance to other agencies, to governments, and to industry. They are used to train students and faculty in the associated universities. They counsel and advise DOE on ongoing and emergency problems.

Technical capabilities. The panel calls them "impressive" but says DOE is inefficient in making best use of them. It says that funding policies are obstacles and the labs labor under much budgetary uncertainty. "Layering and fractionation of managerial and research and development responsibilities in DOE," it adds, "require labs to interact with DOE on an excessive number of horizontal and vertical levels and with heavy reliance on negotiation." There is need for a "coordination and resolution officer at DOE" at the deputy undersecretary level to decide where work is to be done and where it fits into the overall energy policy. The labs should be given two-year appropriations by Congress. Relations between labs and DOE regional operations offices should be at arm's length in policy and program development. The offices are too closely involved in the programs at the labs. Lab directors should be given more flexibility to reprogram resources or start new programs at no less than 5% but no more than 10% of lab budgets.

DOE policies and procedures. The labs are burdened with too much paperwork. Still, research quality at the labs needs improving. Current DOE patent policy is too restrictive for effective technology transfer to industry. A paperwork audit should be done by an outside consultant to improve efficiency of operations. Technical audits of lab research programs also should be done by outside groups. Labs should be allowed to do more work for outsiders.

Lab involvement in DOE energy objectives. DOE has a vision of how labs could be used for research policy leadership. Lab staffs are not used in department planning. Lead mission assignments are ineffective and given reluctantly; DOE has no commitment to them. More training programs with universities are needed. Research and development at labs is not done enough with needs of end-user in mind. Technology transfer activities need a lot of improvement.

Other strategies for making best use of labs. Minimum funding will deteriorate the quality of research at the labs. If cuts have to continue, the best programs should be preserved. So options would be to give labs some work by other agency labs, narrow the missions of the labs, shut some down, or merge them with others.

that looked at us," recalls Postma, "derided us for being too diversified. We were working in energy conservation before it became a buzzword in the 1970s. The facts are that NASA's Jet Propulsion Laboratory at Caltech got $70 million from DOE to work on solar energy and conservation, more money than any of the DOE labs had in nonnuclear energy. No one complained about a NASA laboratory being in the energy business. It galled me to see us chided for diversifying out of our interests when DOE money in our area of expertise went mostly to a non-DOE lab. But we are over that now. Still, it's hell to get beat over the head for just doing your job."

"DOE was very coherent in its projections for us five years ago," says James M. Williams, chief of planning and analysis at Los Alamos. "But since Reagan, DOE has had no clear picture of where we ought to go. So it has been a difficult time for us to plan because we don't know the response. So we've been emphasizing areas where we see the most growth potential—in the case of Los Alamos, weapons work and such long-term areas as fusion."

"One of our problems," says another official at Los Alamos, "is that there are too many industrial concerns at the federal trough and they are competing with each other and with the labs. And in many projects it isn't clear that what they do is any different from what the national labs do. If we're going to be assessing the role of the labs we ought to be assessing the whole issue of federal funding rather than industrial relationships. Many contractors are producing useless gold-plated widgets for [the Department of Defense] or DOE and we ought to take a look at who those guys are."

The study panels are characterized by solid establishment figures. One group was assembled by the Energy Research Advisory Board (ERAB) and was headed by Ivan L. Bennett Jr., dean of the New York University school of medicine. It finished its work last September with release of its report. A second was organized by the

White House Office of Science & Technology Policy (OSTP) under David Packard of Hewlett-Packard. This group is assessing the future of all the national laboratories from health to agriculture, and a first draft of its report is on Keyworth's desk. The third is a subunit of the National Commission on Cost Reduction by Government. Its panel on energy, headed by Roger Milliken, chairman of the big, privately owned textile company, Deering Milliken Inc., has been looking into improving the efficiency of the labs in line with the Reagan Administration's smaller is better philosophy.

Although all the panels have finished their work, only the ERAB report has been issued. But what they each learned is that the laboratories as reservoirs of technical talent are indeed special.

Says Sandia president George C. Dacey, "I think the ERAB group finally came around to seeing the fundamentals it missed in its early investigations. Its final report was 180 degrees out of phase with its early draft. And I understand that reports being done by the General Accounting Office and OSTP are very similar in tone. They were first asking whether research and development should be the core in universities, industry, or the labs. In truth, there are industrial and academic labs that are indistinguishable from the national labs. It wasn't appreciated that a lab like Los Alamos or Sandia becomes an excellent institution over a number of years. It takes a lab that long to become a national resource."

Though bathed in myth and lore, the national labs are only latter-day entries into the federal government's research spectrum. Everyone has heard of the National Institutes of Health, national laboratories with a budget of $3 billion. The Department of Agriculture pioneered the idea of the national laboratory geared toward practical needs. The National Bureau of Standards in the Department of Commerce is the one major national laboratory that directly serves industry and technology. The Bureau of Mines has long pursued the science and technologies of understanding and exploiting ores. More recently, the Environmental Protection Agency established a series of centers that grew out of vintage federal programs in sanitary engineering.

If, as the saying goes, the South can't eat magnolias in the face of meeting modern problems, the laboratories can't live off a past laced with the sense of hubris so characteristic of physicists. Today's buzzwords in science and technology policy are "innovation and productivity," on which the government speaks in rotund terms but still has no comprehensive policy. If that's the case, questions are raised over what role these laboratories have in contributing to the next era of U.S. science and technology with so many industrial and university research facilities competing for the same R&D funds. None of the centers were ever much of a focus for the economic development of regions through high technology, though each is located in the main geographic areas of the country. In short, there was little sense of integration with larger problems and now the fear is that history has passed them by despite individual zones of technical excellence at each lab.

"There are a lot of federal laboratories that could be shut down and nobody would know the difference," says one Congressional staffer who has viewed the parade of science policy fads and fashions over three decades. "I just can't get too excited about the issue. If I had my way, I'd have a sunset provision on them all. When they cease to fulfill their major missions, you close them down." And as for the argument that phasing them out would squander important talent and resources, this staffer sees such an argument as bunk. Good scientists usually can find good jobs.

The House Science & Technology Committee, ever alert in its search for issues to bring to its hearing rooms, will be continuing its series of inquiries on the laboratories this year. The first of them began in July of 1981 (The Future of the Department of Energy's Multiprogram Laboratories), continued through June 2, 1982 (Impacts of Budget Uncertainties of DOE's National Laboratories), and ended last December (The Future of DOE's Multiprogram Laboratories). The next chapter in the series will examine how well the labs are transferring their technology and science to social, economic, and industrial needs.

"I don't think you can overstress the importance of this national laboratories issue," says staffer Ezra Heitowitt, who once worked at Oak Ridge. "We really are at a point where people are concerned about the health of the U.S. technological enterprise and international competitiveness and we want to know how well science and technology are doing the job, especially in places where you already have a tradition of excellence. We want to know how you can make them more responsive. We want to look at how the government is removing the barriers to that transfer of technology."

One thing the committee will be examining is relationships of the laboratories with their contractors. Each of them is run by an outside group—Argonne by the University of Chicago; Los Alamos, Livermore, and Berkeley by the University of California Regents; Brookhaven by Associated Universities; Oak Ridge by Union Carbide; Pacific Northwest by Battelle Memorial Institute; and Sandia by Western Electric. The influence each contractor has over the program of the labs varies with the contractor. The University of California Regents pay close attention to programs at Livermore, Los Alamos, and Berkeley and do the actual choosing of laboratory directors.

One academic who knows at least one laboratory well is E. G. Meyer, vice president for research at the University of Wyoming. In the mid-1970s Meyer led a group of universities in the Western Mountain Region in an attempt to replace the University of California as Los Alamos' contractor. He felt the move made sense because Los Alamos was, after all, in their region. Because Los Alamos was diversifying, Meyer believed the new university arrangement would bring the laboratory more into the sphere of regional problem solving. As Meyer reports it, DOE sent the bid back with the envelope unopened. He is no fan of the labs.

"In fact," Meyer says, "the words 'national laboratory' injure me a little. These labs are funded by DOE and run by contractors. They are not national laboratories like the National Bureau of Standards or the Energy Technology Centers are. The words are used too much in the

Madison Avenue sense. They are very good, they have a lot of money. But they can't do everything by any means There's no real external review of their programs."

Los Alamos did try to woo the universities in the region when its meson physics facility was built. "It wasn't until they wanted to build their accelerator and were facing competition from universities for the facility that they came to us," Meyer acknowledges. "So we joined forces in petitioning the Atomic Energy Commission to build the facility there." But as time went on, relationships soured.

"By the late 1960s, when weapons work began declining," Meyer says, "they began looking around for new projects. The trouble was that universities were moving in the same directions. So competition developed. The universities resented the fact that the labs were doing things the universities were staffed and able to do. They even branched into the socioeconomic area and contacted state agencies with proposals to do environmental impact studies for them. So the labs were getting away from their original mission, nuclear physics, and we didn't like it."

Laboratory/contractor politics is the hottest technical issue currently raging in Tennessee with the announcement by Carbide that they no longer are interested in running the Oak Ridge complex that includes the laboratory, allied weapons development, and uranium enrichment activities. The company has told DOE that it will run the facilities until 1986 if need be. But the bidding already has begun, with some 60 groups expressing interest. One of them is the University of Tennessee, which sees in such a contract both a financial and academic bonanza if it is selected. The university sees itself becoming a great research institution and has dreams of expensive $100,000 distinguished Nobel Prize-level professorships funded through income from fees and overhead. DOE sources say the university's dream is of the pipe variety. Contractors, they say, don't make that much profit running a national laboratory. What the university would indeed gain would be adjunct laboratory facilities. Considerable University of Tennessee research is done at Oak Ridge, and several graduate students perform their thesis work in the Oak Ridge laboratories.

If each laboratory today lacks a discrete identity, there are moves to find for each of them one overriding national mission. The Energy Research Advisory Board's special panel on the multipurpose laboratories says DOE should seek for them a "broader laboratory role in innovation and productivity in the national economic interest."

But still needed is a basic federal concept in publicly supported research and development. Coming up with one isn't easy; but there are models. For example, the National Fertilizer Development Center run by the Tennessee Valley Authority in Muscle Shoals, Ala., directly engages in product development without interference from the Administration. The models being sought have more to do with developing methods of interaction between federal technical people and those in industry.

And the laboratories do here and there display models of laboratory-industry technology transfer. Oak Ridge, for example, is the leading laboratory for energy conservation (a concept not in favor by the Administration as a national laboratory activity). During the 1970s Oak Ridge engineers developed a water heater based on a heat pump as its source of energy. Oak Ridge asked Amana to look at it; Amana was impressed and obtained advance waivers from DOE on patent and licensing rights derived from work their employees did at Oak Ridge. They perfected the device and marketed it.

"Activities like this raise lots of questions," says Oak Ridge director Postma, "like why a sophisticated lab like ours is doing such a thing. Our role is that of agents for DOE policies." In the 1970s it was in fact DOE's policy to drive energy conservation technology into the private sector and it gave the labs the job. Now the policy has been turned around and made something the market itself should determine.

What the laboratories are doing now is establishing offices mandated by the Stevenson-Wydler Technology Innovation Act of 1980 to search out promising technologies and try to market them to potential industrial users. What is needed, all of the labs say, is a uniform patent policy at the department level that would give the laboratories the freedom to do more autonomous negotiating. What they want most is for DOE field offices to stay out of their hair.

One semisubversive way of keeping them out is through the Federal Laboratory Consortium, a network begun by Defense Department facilities to serve as technical shock troops whenever national, regional, or local problems erupt. Just as the Army or National Guard help out in emergencies, the consortium will call on scientists or engineers to offer their services. Staffers are allowed to devote 3% of their work time to the consortium, and some directors point to that activity as a form of technology transfer in the more public arena. The consortium was activated, for example, when the Three Mile Island crisis erupted in 1979. Countless smaller, less heralded examples also exist. But despite the existence of the consortium, one looks in vain for a sense of bureaucratic community among the labs. There is only scant dialogue among them. Directors usually meet only once a year, although there is more contact now that technology transfer is the current major concern at DOE headquarters. And it is rare that one gives credit to another for overlapping work done elsewhere. Los Alamos and Livermore are the best examples of open rivalry and jealousy. And on the more daily level, it was a surprise to some that during the press conference at which the Berkeley Lab announced establishment of its center for research on advanced materials, nothing was mentioned about the creative industrial participation around the synchrotron light source developed at Brookhaven.

But politics are a necessity when issues like saving the laboratory are paramount. And in politics one takes one's chances. The materials sciences community wasn't too happy about not being involved in the planning of the center. "Shirley was trying to keep alive his laboratory by inventing a bogus raison d'être around materials science," says Rustum Roy, head of the materials sciences

Focus of Pacific Northwest Lab is radiation research

The Pacific Northwest Laboratory began as the Hanford Engineering Works in 1943 and was one of the three "secret cities" involved in the development of the atomic bomb. More than 140,000 workers were involved in the construction of the reactors that produced plutonium between 1943 and 1945. Some stayed. Most stayed only a few weeks, succumbing to the isolated, shantytown, militarized life in what is in reality a desert in that part of Washington state.

Battelle Memorial Institute actually makes up only a fraction of the total technical force at the Hanford facility (known as the "Area" locally). Atlantic Richfield runs the nuclear waste reprocessing and storage program there; United Nuclear Industries operates the dual purpose nuclear reactor that produces Pu-239 and generates electricity for the northwest region; and Westinghouse operates the Hanford Engineering Development Laboratory, whose gem is the fast-flux test facility for research on the sodium-cooled breeder reactor concepts.

Battelle runs the laboratory in an arrangement that is unique among all the labs. Though they are all contractor-operated, the Department of Energy allows Battelle to use laboratory staff to work on projects funded by private Battelle contractors. The result is a seemingly complicated accounting system by which researchers and other personnel divide their work hours according to project. A chemist may simultaneously be studying nuclear waste disposal techniques under DOE funding and also be spending some time analyzing the properties of a new ceramic for an industrial client.

Olesen: operation works well for Battelle, DOE, and the region

How this system came about goes back to 1964 when the test ban treaty drastically reduced nuclear testing. The result was the shutting down of nine of the 10 plutonium-producing plants and an enormous reduction of the work force. At the time, the so-called Tri-Cities area was wholly dependent on the Hanford works and a committee was formed to work out ways of preserving the scientific and engineering talent in the area. Battelle offered to come in and try to re-establish a technical base. The experiment worked, or has worked so far, and by that decision a national laboratory began playing a direct role in the sustenance of a regional economy.

Today, PNL does work on radiation effects on materials, radiobiology, terrestrial and aquatic ecology, atmospheric sciences, radiological physics, the beneficial aspects of radiation, nuclear waste management, reactor siting, and general energy development work. Like the forested environmental research park at Oak Ridge, PNL operates a 110-square-mile arid lands ecology reserve in the Washington desert. Moreover, it is trying to help the Washington Public Power Co. deal with the $10 billion financial disaster it is facing by stopping construction of three large nuclear power plants. This fiasco came about by poor planning and failure to anticipate the costs of construction and safety.

PNL's director, Douglas Olesen, sees the operation as a big success that works well for Battelle, DOE, and the region. PNL has yet to work out a system of technology transfer between the federally funded research and the private sector. One would think that Battelle, with its know-how in the patenting and licensing of research also would lend its talents to the government for that purpose. But either no one has thought of extending the philosophy to the patent field or the idea is simply seen as not feasible. Still, if the laboratories are contractor operated, DOE would appear to need to rethink the purpose of such an arrangement, especially if innovation and productivity are the new themes around federal laboratory research.

Olesen is impressed with the Energy Research Advisory Board report, but says he doubts that its major recommendations can be implemented. "Unless there's a massive overhaul of DOE," he says, "the idea of having an undersecretary in charge of the laboratories just wouldn't work. We have pragmatic assistant secretaries now who decide how the work gets done in various areas and how it gets funded. As long as those people have programs it would be difficult to have somebody else deciding how things would get done."

laboratory at Pennsylvania State University. "Everyone knows that the big movement today in materials is processing. And the real innovations in ceramics were, in fact, demolished in the national laboratories by this Administration."

The laboratories try to do technological transfer and succeed some of the time. However, there appear to be no firm principles of policy and action; no dialogue between business and the government's R&D sectors on the issue. No one appears to be taking the lead.

The situation is understandable, and Berkeley will be encountering the problem soon enough when it tries to draw companies into the center. "Over the years," says George C. Pimentel, director of the Berkeley lab's Laboratory for Chemical Biodynamics, "it's been a traumatic business trying to get into this new world when it's no longer [possible] to say Berkeley is the world center of high-energy physics. So LBL is feeling out the ground in industry cooperation. I'm not sure we really know what we're talking about. I have people in the biodynamics lab who wanted to do an experiment with IBM in San Jose. The negotiations dragged on for a year and a half and IBM finally said they weren't interested anymore and they left. So that closed the door. Now we're trying to get the door back open through the university, and this brings in a different cadre of lawyers, those of the university rather than just DOE. If DOE wants these connections to happen, they'll have to agree to bringing it down to a two-party arrangement."

Warren E. Winsche, deputy director of Brookhaven, has a related view. "We are trying to evolve with a system that is changing, but we haven't come to grips with it yet," he says. "We got some money from Exxon. We like it but we're not going around asking for a lot of industrial money because companies always want to know what they are buying. At the same time, American industry is so internationalized that what they learn from us could easily go to a foreign government anyway."

Winsche, moreover, doesn't take too gloomy a view of the situation at Brookhaven. "We might be down now," he says, "but we're still much higher than we were the last time we hit bottom. In 1972–73 we were down to about 2400 people. Our current level is 3100." He does regret that Brookhaven's proposed research showcase, a Center for Structural Biology, was rejected by DOE; but he remains optimistic even though he expects as many as 200 more personnel cuts as DOE continues its cuts of fossil fuel, alternative energy, environmental, and biomedical research. "I don't think we feel vulnerable," he says. "We have strong interaction with the universities and a growing interaction with industry." And although he couldn't get the biology center, there's a good chance DOE will give the nod to upgrading Brookhaven's research reactor, the only strong source of neutron beams in the country and with only one competitor, a reactor in Grenoble, France.

To debate the future role of the laboratories is to place oneself in the mainstream of debate about science policy and the social and economic future of the country. That's the kind of dialogue one might hear at the end of long discussions about high-flux test facilities or proton-proton colliding accelerators. But that may be the core issue that could determine their fate. In a technical world so internationally intertwined, a world where the U.S. is grudgingly admitting that the Japanese lead not only managerially but technically, one has to ask what the nature of the technological "competition" really means. There is little dialogue within the labs on this issue. In the weapons labs, the questions of national security revolve only around weapons superiority. But there is concern about America's "technical illiteracy" and the directors have no problems addressing that.

"Real or imaginary, some of us sense a public disaffection with science and technology," says Los Alamos' Kerr. "It's not clear whether the supply of scientists and engineers is affected. But if we think this generation of

Keyworth: labs should have set of missions conforming to national goals

White House Science Adviser George A. Keyworth II gives his views of the national laboratories in an interview with C&EN's Wil Lepkowski.

C&EN: Have you changed your attitude toward the labs since a year ago when you said there was a lot of work they shouldn't be doing?

Keyworth: No, and a lot of people studying the laboratories have come to the same conclusions. And that is that you have a resource making an enormous expenditure of federal dollars and, more important, an enormous assemblage of facilities and talents that could be used vastly more effectively to address the two top priorities of the country: to maintain our superior defense technology or perhaps to improve the competitiveness of U.S. industry.

C&EN: Over the past year, what's been done to bring that about?

Keyworth: We have made serious efforts in the budget to provide clearer missions by stressing areas that are national priorities. But most of all we have tried to explain our policy as much as possible in the hope that the national laboratories would come up with their own mission and directions. And I would say that this has largely not happened. We're trying to create a model that we hope will have the input from the industrial sector as well as from the scientific community.

C&EN: Any other large thrusts in the labs?

Keyworth: I could point to a lot of small ones. But the main idea is that we are not going to turn two-generation-old institutions around as rapidly as the nation is changing. And we can't do it by pushing from the federal government. You've got to do it internally; you've got to do it by bringing industry closer and closer to the process in setting missions, directions, and priorities.

We have built since the Sputnik era an environment in which there's a widespread perception in academia and in many of our national laboratories that good creative research is inconsistent with the profit motive. I think that's an attitude that's inconsistent with the fact that we're facing such strong challenges from Japan and Western Europe and even occasionally from the Soviet Union, so that if we don't optimize our own ability to innovate and improve technology then we'll start to lose, badly.

C&EN: Do you foresee any of the nonweapon laboratories being phased out?

Keyworth: I just don't think the political system would support that. What I think we will see is some laboratories being more responsive than others. Some will receive more impetus in establishing their new missions, like Lawrence Berkeley Laboratory is doing right now. If they do that well, and carry it out effectively, I think it will ensure a long duration of vitality. We are not in a period of unrestrained economic growth. We don't have money to burn.

C&EN: One of the problems in so-called innovative ideas is that, as the labs put

it, they are restrained by the bureaucratic procedures at DOE.

Keyworth: You hit a nail on the head. It is a strange thing that the ideas and priorities used to come from the laboratories. And it worked. And today, they don't have as many ideas; when they do, they have to march through this excessive bureaucracy. I'm not sure how to walk backward in time, but I do know that the DOE bureaucracy is excessive. I do have some skepticism whether the government is capable of providing a sustained sense of clear direction. This is one of the reasons I keep harping on the fact that we need more industry involvement. We really do have a generation of leadership in high-technology industries that have a sense of vision. And I think those people should have brought more into the guidance and management process.

C&EN: Do you think the laboratories will establish marketing policies for moving their technology into the private sector? And how would one do that, given your feeling that the labs are hindered in taking initiatives by the DOE bureaucracy?

Keyworth: Nobody ever gives the Administration much credit for this, but did you ever stop to think that we had a reason for dismantling DOE? We have built a monster. It neither handles operations of R&D effectively the way AEC did nor does it stimulate effectively energy development. It has become a large, unwieldy federal bureaucracy.

C&EN: What will OSTP's Federal Laboratories Panel say about the labs?

Keyworth: They will clearly talk about more explicit mission definitions, more involvement with industry in setting priorities; they will talk about more institutional independence in proposing means by which the missions can be met. Those are the big things. They will talk about developing the means by which performance is judged. We're months away from that report.

C&EN: There seems to be no tendency to look ahead and anticipate problems among these labs. You'd think there'd be anticipatory studies.

Keyworth: I'd blame the Energy Department and ERDA for that. First of all, such an overhead of paperwork was created, so many studies done, that it was difficult to get people the credibility on the outcome of that study. Second, when you work for an agency whose mission is not taken as credible—such as the objective to meet 20% of the nation's energy requirement [by conversion] to solar by 1990—when such a technically infeasible objective is established, then it is not surprising that the labs find themselves embarking on paths that have very little relation to reality. So I think it's been a demoralizing experience for them. When they were building the atomic bomb, it was a very crisp, short-term goal, and they went at that with verve and imagination. By the time they got on to the energy mission the energy crisis was already over. The market was stabilized so that there was no longer a crisis and a lot of the vitality was lost. They're suffering now from the problems of old age.

kids standing before their videogames can lead into understanding of problems of the man-machine interface, we're kidding ourselves." It's that combined with the quick fix mentality.

Sandia's Dacey is concerned, too. "I think the antitechnology attitude in this country and elsewhere is destructive. It's hard to know why we are doing this. It was easier to understand during the 1960s when it was carried out by young people on the social fringes. But now you have institutions like the Catholic Church and the American Bar Association taking stands against military security. And most serious is that these positions are not informed. The people doing the most vocal lobbying don't have the facts straight."

Many high-technology presumptions do need examining, however. For example, one justification for nuclear energy development lies in citing the consequences of population growth around the world. The argument goes that the only way of solving human misery is in the supply of electrical power to the developing countries. The problem is that the developing countries are poor and nuclear energy is the most capital-intensive energy ever invented. They simply can't afford it, and in the future probably will be less able to do so. Yet no national laboratory is devoted to solving the energy problems of the developing countries in terms of the limits to capital. Indeed, those with projects around alternative sources of energy lost their DOE support under the Reagan Administration.

"The big question," says science policy analyst Christopher Wright of the Carnegie Institution of Washington in Washington, D.C., "is to what degree basic and applied science supports the life support system." Wright, who grew up in Los Alamos during the bomb development work, says Washington technology policy planners scarcely know how to ask the questions in a systematic way, and the Reagan Administration believes documents like the Global 2000 report on technology's dangers to the environment are opposed to business and thus aren't worth considering.

Therefore, because the labs are multipurpose, the concerns they raise are multifaceted. The high-technology energy models that the developing countries are being forced to assume may simply not be the right ones. And the alternative models appear to be what this Administration wants least. Weinberg was once engaged in an interlaboratory conference on converting the labs to sociotechnical centers that would assess these issues. But nothing ever came of it.

A couple of the labs, for example, do look at, say, the effects of carbon dioxide on Earth's climate. But there is no systematic federal effort to deal with threats to the system as perceived by the highest expertise.

"Every new technology," says William Marcuse, head

BEST AVAILABLE COPY

All laboratories except weapons facilities at Los Alamos, Livermore, and Sandia are experiencing manpower cuts

	Budget[a] ($ million)		Staff size[a]		Scientists/ engineers ratio	Approximate % of budget 1982[a]			
	1979	1983	1979	1983		Weapons	Nuclear energy	Basic physics	Biology/ environment/ basic energy sciences
Argonne	$260	$252	5070	4230	5/3	1%	36%	3%	28
Berkeley	141	132	3070	2430	7/3	2	1	37	25
Brookhaven	162	210	3520	3220	7/3	0	1	39	30
Livermore	396	730	7010	7380	8/5	51	20[b]	neg	4
Los Alamos	398	576	6800	6900	2/1	48	7	8	5
Oak Ridge	313	366	5000	4430	3/2	9[c]	40	21	22
Pacific Northwest	122	153	2100	1830	5/3	17	25	0	31
Sandia	489	900	7600	7950	3/5	67	5	0	7

a Fiscal year. b Fusion. c Imprecise: Oak Ridge National Laboratory serves as backup for uranium production and enrichment work done at Oak Ridge complex. neg = negligible.
Source: Department of Energy

of the office of research and technical assessment at Brookhaven, "has associated with it lots of problems. There are health problems associated with production, environmental problems with waste, both health and environment with disposal of these products. The strange thing is that this Administration refuses to see those issues as a component of science policy. A coordinated research policy would have to include the biomedical, economical, and ecological impacts of what we are doing. Another thing the Administration refuses to do is to generate a research policy that anticipates all of these elements. As it is, we remain much too discipline-oriented in a time when so many problems are related."

And Sandia's Dacey's concern about the powerful rise of antitechnology forces within established institutions could be off the mark. Sophisticated scientists do think that the lab directors could be less hawkish on matters of national security. One of them is Hugh DeWitt, a plasma physicist at Livermore.

"Lab management considers me a pain in the neck," DeWitt admits. "My interest has always been more in basic physics than in weapons. I've been out to improve the scientific climate at this lab because the problem with Livermore is that it has become more and more an engineering lab. And the University of California Regents take no role in establishing the policies."

But what disturbs DeWitt most is the lack of internal debate over the implications of the arms race. "The Regents are no help there, either," he says. DeWitt says the laboratory directors play too heavy a role in arguing for extensions of arms buildup.

"During the 1977–78 debate on the arms limitation treaty, Energy Secretary James Schlesinger became worried that it would pass, and he brought Roger E. Batzel (director of Livermore) and Harold Agnew (then director of Los Alamos) to Carter to urge him to keep testing. This made a lot of us quite sick. But they've been doing this since 1957. These directors enjoy great influence in Washington. They have a strong vested interest in continuing weapons work. They oppose any realistic arms limitations schemes. People who rise up in lab management take the hawkish orientation and they believe the way to national security is to have an impregnable offense.

"I'd like to see the university have more say in the policies of these labs. I agree that the University of California is probably the best institution to operate these labs. If they were run by someone else there might be less public scrutiny of what they do. The university at least has a tradition of encouraging free debate and controversy and protecting its faculty, even though at a place like Livermore the management would rather not have people like me around. Most of the research and development people are simply high-level technicians who give little thought to the dangers of what they are doing."

Former Livermore director Herbert F. York, now a professor of physics at the University of California, San Diego, thinks that in the absence of any creative dialogue on arms control, the labs should continue to be doing exactly what they are doing. The people at the labs do participate in dialogue on arms control and national security, he says, but only in the context of current strategic nuclear policies. There are nonmilitary threats to security, of course, but he thinks that other institutions are better adapted to studying such dangers as overpopulation and food supply.

The national laboratories are a collection of a lot of talented people who have been in the middle of many controversies over the years. As Alvin W. Trivelpiece, director of DOE's Office of Energy Research, says, "By and large it's better that there be a little trauma than just having a static situation. It makes for more dynamic institutions." For the labs' critics, the issue is more than dynamism. It's more like a guiding vision. □

Chlor-Alkalies Begin Long Climb Up From Recession

Badly battered in 1982, chlorine, caustic soda, and soda ash face slow growth; for chlorine/caustic, more plant shutdowns are likely

Bruce F. Greek, C&EN Houston

U.S. producers of the major chlor-alkalies—chlorine, caustic soda (sodium hydroxide), and soda ash (sodium carbonate)—knew business had weakened a year ago (C&EN, March 1, 1982, page 10), but they expected a pickup later in the year. Instead, things got even worse.

Unbelievably, plant use for chlorine/caustic sank to 60% and even below, an astounding level for plants traditionally run from 80 to 95% even in bad years. Output fell 15% from 1981. Prices remained shattered in chlorine and fell back from dizzy heights for caustic soda.

In soda ash, the new prosperity from heavy investment in natural product facilities in Wyoming had to take a breather. Here, the mine use rate retreated to 75% in 1982, output dropped 6% from 1981, and prices finally gave ground.

Chlor-alkali producers believe they hit bottom at last about the end of 1982 and finally can move up again this year. However, it will be slow going.

Key Chemicals

Growth rates predicted for the rest of this decade are no better than the 1970s for these slow-moving commodities. For example, the large capital outlays of the past five years in soda ash could yield average annual production growth of just 1.5%, say pessimists. Maybe 3%, say optimists.

Coming growth rates predicted for chlorine and caustic soda are no better, about 1 to 3% per year. A small demand differential is likely to continue between the two with caustic in the lead. This could produce the same shortfall and high prices for caustic supplies as before the 1982 recession. High caustic prices could then help soda ash producers in their campaign to displace caustic in various uses.

For now, such efforts to gain market share are on hold like everything else in the business, including expensive technology switchovers and capacity additions. The overriding objective for 1983 and 1984 is basic recovery in business volume. Later in the decade, money may become available for the important technical and capacity advances producers would like to make.

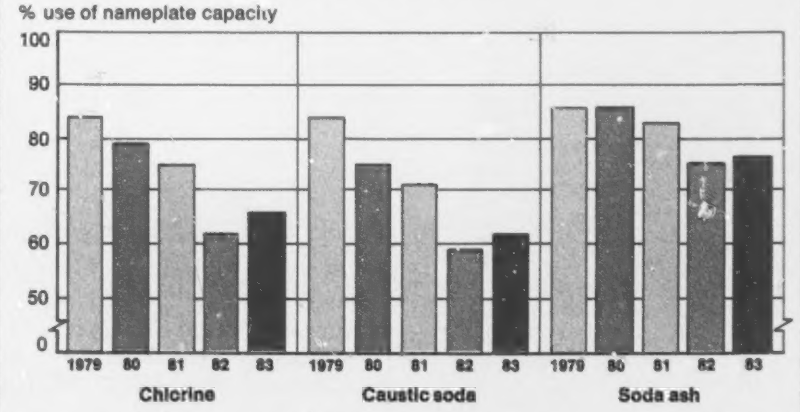
Instead, capacity shakeout is the trend of the moment. How much electrolysis capacity in chlorine/caustic will be shut down permanently is the big question. Some analysts estimate that as much as 700,000 tons per year of capacity (about 5%) will be taken off the list this year for lack of profitability. More could follow in 1984.

Longer term, unless product value and profitability rise, many more plant shutdowns could be coming. For chlorine and caustic, as much as 2 million tons per year of capacity could remain unneeded through the end of the decade.

For soda ash, the situation is not nearly as severe, but new technology may still force changes. Specifically, a general switch to coal-supplied energy and to solution mining, both potentially important efficiency boosters in trona mining, could sound the death knell for any other U.S. soda ash production. Internationally, U.S. soda ash could then become so cheap that politically erected barriers to it abroad would simply be overwhelmed.

For the more immediate market outlook on the major chlor-alkalies, see the following pages.

Plant use levels could edge up in 1983



Sources: Industry and C&EN estimates, Chlorine Institute, Bureau of Mines

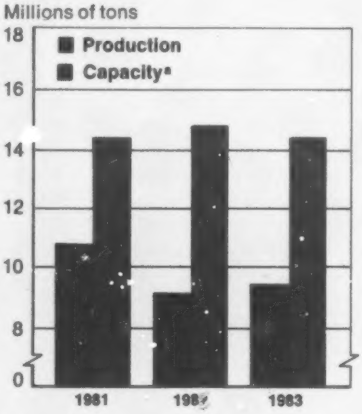
Key Chemicals

Cl_2

Chlorine

- ***Output at bottom***
- ***Capacity down***
- ***Drastic price discounts***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Electrolysis of NaCl brine; recovery from hydrochloric acid; coproduction with metals; electrolysis of KCl brine

MAJOR DERIVATIVES (U.S.)

Ethylene dichloride 20%, other C_1, C_2 hydrocarbons 10%

MAJOR END USES (U.S.)

Organic chemicals and plastics 70%, pulp and paper 10%

FOREIGN TRADE

Negligible

PRICES

List price $145 per ton on Gulf Coast; discounting general and severe

COMMERCIAL VALUE

$1.25 billion for production, 1983

The historical downturn in chlorine's fortunes that began in the mid-1970s shows little sign of a letup in 1983. Already shaken before the 1982 recession, chlorine took a fearsome beating last year, with prices discounted as much as half or more. The product's capacity-building wave of recent years finally ended, and the new economic reality forced producers into the first round of plant shutdowns. More closings are in the works this year in the face of a mild recovery pace.

For 1982, U.S. chlorine production totaled some 9.2 million tons, down 1.5 million tons from 1981 production, or 14%. This percentage decline was exceeded only once in recent decades, when in the 1975 recession production dropped 15%, according to the Chlorine Institute.

Analysts' outlook for 1983 varies widely depending on assumptions about the strength of the economic recovery now under way. As with many other big-volume chemicals, the divergence of opinion is causing more uncertainty than usual about chlorine volume. Current forecasts for 1983 production range between a small upturn of 2% to 9.4 million tons to a 17% rebound back to 1981's 10.8 million tons.

However, unless recovery becomes much more vigorous than it is now, the chlorine production gain likely will stick to the low end of the scale, according to most industry sources. Rising demand for chlorine in derivatives, pulp and paper manufacture, and water treating—the traditionally important uses—will lift chlorine output modestly. But inventory rebuilding isn't expected to be a big additional production booster.

Operation at chlorine plants fell below 60% of nameplate capacity for parts of 1982. Unfortunately, capacity hit the highest level ever in February 1982 at 40,700 tons per day, according to the Chlorine Institute. The inevitable followed, and capacity fell over the rest of the year by a bit more than 1000 tons per day. Even with this decline, the industry's operating rate slid off during the year. Obviously, closings did not keep pace with the production sag, which in December was still 10% from December 1981.

Under pressure of reduced demand, additional chlorine capacity now has been shut down. Estimates of total shut-down capacity are about 2000 tons per day, bringing operating capacity to about 38,700 tons per day or somewhat below 14 million tons per year. During 1983, more capacity might be shut down, as much as 2000 tons per day, say some industry sources.

These shutdowns definitely will pick up chlorine operating rates this year, especially if demand improves more than pessimists expect. For example, if capacity stayed flat in 1983, the operating rate would be 67% of capacity to produce 9.5 million tons of chlorine. If capacity declines to 36,700 tons per day (13.3 million tons per year), the use rate could rise to 72%. Additional gains would come in capacity use in 1984 if demand edges up another 2 to 3%.

Chlorine's demand slump in 1982 came from the slump in demand for derivative chloro-organic chemicals, most importantly polyvinyl chloride. This drop exacerbated a general demand reversal since the mid-1970s. Before then, a shift in the chlorine use pattern to greater dominance by derivatives aided the rapid growth of chlorine capacity. However, in the late 1970s and 1980s, consumers turned away from many products containing chlorine or made using chlorine. The result today is a slump leading to capacity shutdowns. The consumer switch probably won't change chlorine's use pattern much but won't help demand growth either, according to the near-term outlook from one industry analyst.

Uses of chlorine other than chloro-organics also are struggling under the recession. For example, chlorine's market in wood pulp and paper is staggering under paper's competition from plastics in packaging uses. Chlorine also suffers from lower consumer demand for brightness in paper. Competition for chlorine from other bleaching materials in paper waxes and wanes with economics. On balance, this competition generally is considered less difficult to meet than is paper's challenge from plastic as packaging.

So for 1983, chlorine producers have reconciled past ambitions with the current reality of a modest recovery following a severe downturn. Capacity shakeout and patience will be the most likely tactic this year.

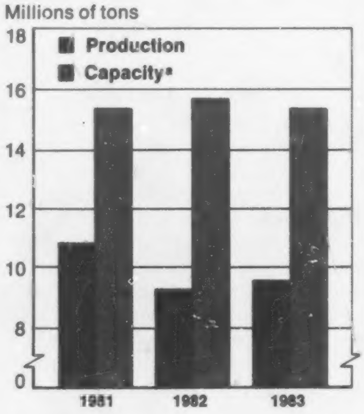
Key Chemicals

NaOH

Caustic Soda

- ***Demand weak***
- ***Capacity shaved***
- ***Prices hauled down***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Electrolysis of NaCl brine

MAJOR DERIVATIVES (U.S.)

None

MAJOR END USES (U.S.)

Chemical manufacture 50%, pulp and paper 20%, soap and detergents 5%

FOREIGN TRADE

Exports—easing to about 1 million tons in 1983; imports—rising to more than 100,000 tons

PRICES

List price about $230 per ton for 50% liquid; discounting significant

COMMERCIAL VALUE

$2.25 billion for production, 1983

Chlorine went from bad to worse in 1982 but never was expected to do well. For coproduct caustic soda, however, 1982 was a true shock.

Caustic started 1982 in such tight supply—squeezed by production contraints from chlorine—that price increases seemed a way of life. But all that came to an end. Caustic producers found their favored product turned into a shambles later in the year. At present, prospects are dim for a return to prosperity in 1983.

The list of negatives for caustic in 1982 grew lengthy. In about six months' time, caustic went from allocation among customers to oversupply. List prices fell a fifth or more in the last half of the year. No longer could coproduct chlorine ride on caustic's strong prices, and hard-pressed producers tried to raise chlorine prices at the very time demand was weakening. Caustic's price weakness also was a heavy blow in producers' shift from capacity buildup to capacity reduction.

Production of caustic soda dropped dramatically in 1982 to a bit below 9.3 million tons, down about 15% from 10.9 million tons produced in 1981. The decline for caustic runs larger than for chlorine because caustic is practically all produced from electrolysis of brine, whereas some chlorine is produced by other methods.

And as with chlorine, nameplate capacity for caustic is back to where it was at the beginning of 1981, 15.4 million tons per year. Along with chlorine, caustic is in line for further capacity decline. About the only possibility for expansion is in small plants with new, more energy-efficient cell membranes designed for remote location and in special uses such as in-house production at a pulp mill.

For 1982, caustic production ran at an average rate below 60% of nameplate capacity. Prospects are that this rate will climb back over 60% in 1983 because of a small increase in demand and declines in capacity.

The upturn in caustic demand this year would follow a general upturn in the chemical industry. Other chemicals make up half the U.S. use of caustic, although not very much caustic appears in the final product. Most caustic used in chemicals acts as a carrier or neutralizer just as in all but a small percentage of caustic's other uses. Most of caustic's large exports are consumed the same way, for example in making alumina from bauxite.

Chemical uses of caustic in turn vary as consumer demand affects end products. For example, aluminum demand has been hit hard by higher prices and recycling. Hence, consumption of caustic in both U.S. and export markets to make alumina probably will not grow in 1983 as will caustic's overall neutralization uses. Many of the latter are spurred by environmental concerns reflected in process design improvements, in part the result of statute changes.

Some of these environmental uses of caustic can be satisfied with unfinished caustic liquor straight from the electrochemical cells. This caustic doesn't go through the usual further processing to remove chloride ion and evaporate some water, and may not be reported in official production data. This practice accounts in part for the lower than stoichiometric ratio of caustic to chlorine in production figures. Though hard to pin down, these environmental uses of caustic are expected to continue to grow faster than the average for caustic markets in 1983.

A wide variety of organic chemicals are made using caustic. Prospects for those uses differ, but in general this group is expected to grow at a rate above average for caustic. The large size of this group and its expected growth are behind some analysts' views that caustic could turn tight again later in the economic recovery.

Pulp and paper uses of caustic will stay below caustic's average growth rate because of paper's expected slow recovery from the recession. Recycling of paper and competition for caustic here from soda ash also could tend to dampen growth.

Most other uses of caustic likely will average 2 to 3% growth in 1983 and are not expected to change much later on.

During the rest of 1983, overall caustic use will recover at a pace almost in step with chlorine. This might firm up sagging prices a bit, but the net financial return from electrolyzing brine will provide little profit for producers of caustic and chlorine.

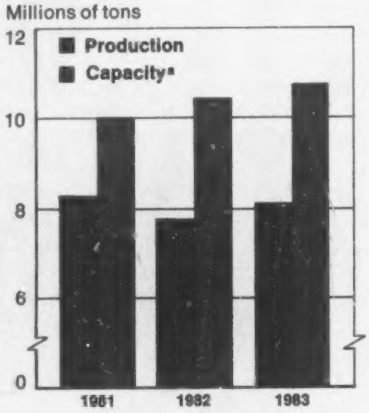
Key Chemicals

Na_2CO_3

Soda Ash

- ***Demand recovery due***
- ***Capacity on hold***
- ***Prices still weak***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Recovered from trona ore or brine; synthesized from salt and limestone using ammonia

MAJOR END USES (U.S.)

Glass 55%, chemical manufacture 20%, pulp and paper 5%, soap and detergents 5%

FOREIGN TRADE

Exports—rising slightly to more than 1.1 million tons in 1983; imports—negligible

PRICES

List price $84 per ton at Wyoming mines; about $40 higher in eastern U.S.

COMMERCIAL VALUE

$700 million for production, 1983

Soda ash has been one of the hotter investment corners in U.S. basic chemicals and has producers excited about prospects later in the decade, when some experts expect U.S. production to dominate world supply (C&EN, Feb. 14, page 23).

But such heady visions don't apply to 1983, just as they didn't to 1982. True, soda ash got through the recession in 1982 in better shape than its alkali cousin, caustic soda. And soda ash also rates higher than caustic in a 1983 recovery.

However, soda ash production still declined about 6% to 7.9 million tons in 1982 from 1981 just as a major new producer, Tenneco, joined the ranks. For 1983, producers expect to recover more than half of this output decline, bringing production to about 8.1 million tons. Unless something very bad happens in exports, the rest of the 1982 decline probably will be regained in 1984.

Capacity moved up in 1982 as the new Tenneco mine and processing plant in Wyoming were completed. Startup of this plant boosted production to create inventory as well as initial volume for sales. However, offsetting Tenneco's output were reductions at other plants due to slowing sales.

For all of 1982, operable capacity apparently ran at about 75% of the nameplate total. This operating rate was down from 1981 but was still good compared to other big-volume chemicals, notably competitor caustic soda. For 1983, the operating rate will be nearly flat because of the 1982 capacity expansion.

The effect of a second straight year of lower operating rates on older plants making soda ash from brine or salt/limestone (Solvay process) opens a bag of speculation. Should the last of the synthetic soda ash plants in the U.S., Allied's at Syracuse, N.Y., be closed, and brine operations at Kerr-McGee at Searles Lake in California be reduced more, then the plant operating rate could get significantly higher—possibly to 85%. However, such changes still may take some time, just as with large potential capacity expansions in Wyoming resulting from development work on lower-cost solution mining of trona ore. Because of current overcapacity and recent dampers put on European sales of imported soda ash, capacity expansion of any kind will remain on the shelf for 1983 except for small additions resulting from improvements in energy and other process efficiencies.

Domestic and export growth for soda ash will continue steady but at low levels after initial recovery from the 1982 recession, analysts predict. The 4% growth in production expected in 1983 will be above the long-term trend, estimated at 1.5% annually. Such a low rate is the result of problems in most major U.S. end uses and exports.

Exports are potentially handicapped by foreign politics and unfavorable economics, according to industry sources. For example, dumping duties in Europe against U.S. soda ash, and the strong dollar relative to other currencies combine to hamper U.S. exports. This year exports still are expected to grow by a small amount from 1982—perhaps 50,000 tons or 4 to 5%—to about 1.15 million tons.

Uses in the U.S., dominated by glass manufacture, face competitive problems, although of a different kind. Glass container markets are hard pressed by improved plastic resins and composites. In particular, soft drink bottles seem in more trouble than ever in 1983.

But plastic containers are only one part of the glass market problem for soda ash. Success is growing in glass recycling, bringing more glass back for reuse as cullet, and further reducing the need for soda ash. Cullet is expected to continue to grow slowly as a material for new glass.

By contrast, flat glass markets finally could give soda ash a lift. Badly hurt by the recession in auto and construction outlets, flat glass is expected to pick up during 1983.

Chemicals manufacture and detergents rank next to glass in importance among uses of soda ash. Again, recovery in demand for various inorganic sodium salts should help soda ash.

Another rising market hope for soda ash producers is to capture markets held by caustic soda in making chemicals and detergents. However, lowered demand and prices for caustic have put a damper on soda ash substitution at the moment, even though soda ash prices also dropped in 1982.

Canadian chemical firms hope slide is over

For Canadian chemical companies, the bad news is that most of them lost money in the fourth quarter of 1982. The good news is that they lost a lot less than they did in the disastrous third quarter.

As a result, Canadian chemical leaders are hoping that 1982's fourth quarter marks the turning point for recovery. Analysts seem to agree that the slide in corporate profits appears to be over. But it will be some time before Canadian chemical companies will be able to regain their earnings peaks of 1980.

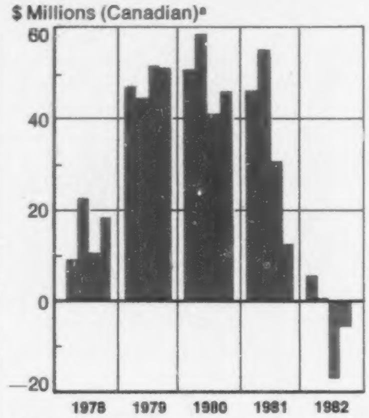
Certainly, 1983 figures appear to be much better than 1982 in both chemical sales and earnings. It could hardly be worse. Last year, for instance, the combined sales of four large, publicly reporting companies (C-I-L Inc., Celanese Canada, Du Pont Canada, and Union Carbide Canada) fell 12.5% from 1981's $3.5 billion (Canadian dollars used throughout this article) to just over $3 billion. The earnings picture is even worse. These four companies earned a combined $144.3 million in 1981. Last year, they lost $15.7 million.

The reasons for this disastrous performance are, by now, all too familiar. The Canadian economy was a shambles last year. As a result, domestic chemical demand was down.

Meanwhile, lower worldwide demand coupled with intense competition for international markets put a crimp in Canada's all-important chemical exports. They fell 11.6% to just over $4 billion.

In the face of this lower demand at home and abroad, Canadian chemical companies couldn't raise prices. Yet, Canada's energy pricing policies saddled them with much higher feedstock costs. Under these circumstances, it was inevitable that earnings would shrink and, in many cases, disappear.

Combined earnings in red in last two quarters



a After-tax earnings of four largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont Canada, and Union Carbide Canada.

Union Carbide Canada, for example, lost $17.9 million last year on sales of $691 million. It was the first loss in the company's 75-year history. Domestic sales dropped 14%; exports were off one third. Company chairman John S. Dewar says that the drop in sales was mostly in volume. Prices remained unchanged while costs increased about 10%.

Dewar says that a major factor in Union Carbide Canada's poor 1982 performance was the higher raw material costs that it had to pay as a result of Canada's fixed schedule of oil and natural gas price increases. And whereas Canadian chemical companies had to cope with these increases, costs were going down for their counterparts in the U.S.

Dewar's sentiments are echoed throughout most of the Canadian chemical industry. Even in C-I-L, a diversified company and the only one of the four major chemical companies to show a profit last year, the 1982 earnings picture was bleak. C-I-L sales fell 7.8% last year, but profits plunged a hefty 72% to only $15.2 million.

With the exception of industrial chemicals and crop protection products, all of C-I-L's business units recorded sales below 1981 levels. Company president and chief executive officer C. H. (Chuck) Hantho says, "The reduction in sales, combined with higher wages and salaries and increased costs of energy-related raw materials continued to have a severe impact on earnings." Those lower earnings led C-I-L to omit dividends in the third and fourth quarters of 1982.

Feedstock costs also come in for a large share of the blame for Du Pont Canada's 1982 operating loss. The company suffered a net loss of $7.4 million on sales of $980 million. Company president J. E. Newall notes that Canadian polyethylene producers are suffering from a significant feedstock cost disadvantage compared with U.S. competitors. U.S. producers, he says, have "used their advantage to reduce prices and capture a larger share of world markets." Although Du Pont Canada's selling prices in the fourth quarter were down 2%, on average, they were down 16% for polyethylene.

Canadian chemical companies have responded to their predicament by delaying or canceling capital spending plans. Layoffs are common throughout the industry.

As a result, many companies think that they will be leaner, tougher, and better able to cope with the recovery when it comes. Noticeable recovery, however, may not come until the second quarter of 1983.

Meanwhile, some Canadian chemical giants are in big financial trouble and may not survive unless they get some government help. This could take the form of relief from oil and gas taxes or direct financial aid.

Earl Anderson, New York

Canadian chemical sales and earnings suffered last year

	FULL-YEAR 1982					
					Profit margin[b]	
$ Millions (Canadian)	Net sales	Change from 1981	Net income[a]	Change from 1981	1982	1981
C-I-L Inc.	$1,059.8	−7.8%	$15.2	−72.0%	1.4%	4.7%
Celanese Canada	323.9	−13.2	−5.6	def	def	5.5
Du Pont Canada	980.0	−14.0	−7.4	def	def	2.9
Union Carbide Canada	691.3	−16.4	−17.9	def	def	4.4
TOTAL	$3055.0	−12.5%	−$15.7	def	def	4.1%

a Net income from continuing operations, excluding extraordinary gains or losses. b Net income as a percentage of sales. def = deficit.

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Academic Gap Between High and Low Achievers Narrowing

Study shows that in the 1970s academic gains in reading by some low achievers was offset by declines in science and math skills of high achievers

A recently released study by the National Assessment of Educational Progress has found that students with poor academic track records made some large gains in reading during the 1970s and held their own in science and mathematics. Most encouraging, NAEP says, are the improvements for black low achievers, who in elementary and junior and senior high schools increased their mathematics performance, and in grade and junior high schools also improved in reading. But at the same time, significant declines in mathematics and science skills were posted for academically able teenagers.

Earlier studies already had documented that grade school students had improved their reading abilities in the 1970s, that junior and senior high school students had declined in mathematics skill, and that senior high students had declined in science performance. But NAEP wanted to probe more deeply.

Explains Beverly L. Anderson, director of NAEP: "We wanted to determine whether students at different achievement levels experienced the same kinds of changes in performance."

NAEP has been carrying out assessments of educational achievement in various areas since 1969. It is funded by the National Institute of Education and administered by the Education Commission of the States, a Denver-based compact of member states and territories for political and professional cooperation in planning for U.S. education.

Learning areas assessed include reading, writing, mathematics, science, citizenship, social studies, literature, art, music, and career and occupational development. In these assessments, NAEP has surveyed the attainments of nine-, 13-, and 17-year-olds, and all areas have been reassessed to detect any important changes. Test items, or exercises, are readministered to the same age group, not to the same people.

The exercises are developed through a consensus process. Over a period of several years, many educators, scholars, and lay persons from across the U.S. design objectives for each subject area, proposing general goals they believe Americans should be achieving through their education. Writers use these objectives to create specific exercises appropriate to the objectives. The exercises then must pass extensive reviews by subject-area specialists, measurement experts, and lay persons.

The exercises are administered to probability samples. The people in the samples are selected so that the assessment results can be generalized to an entire national population—the probable performance of all nine-year-olds in the U.S., for example, based on the performance of about 2500 nine-year-olds in a given exercise. The last science assessment, in the 1976–77 school year, involved about 80,000 students, each taking one of 31 45-minute packages of test items.

For its current, post hoc analysis, NAEP used only two assessments in each of the learning areas: 1972–73 and 1976–77 for science; 1972–73 and 1977–78 for mathematics; and 1974–75 and 1979–80 for reading. It analyzed the data in several ways: by group—black students and white students, for example—and also in terms of students' performance by achievement class and by modal grade.

Achievement classes were determined by partitioning students into

Analysis by age shows performance gains by lowest achievers along with declines by highest achievers. . .

	Age 9		Age 13		Age 17	
Change[a]	Lowest	Highest	Lowest	Highest	Lowest	Highest
Reading	5.0%[b]	1.4%[b]	1.4%[b]	−0.3%	−1.0%	−0.4%
Science	1.0	−2.5[b]	1.5[b]	−2.6[b]	0.6	−3.9[b]
Mathematics	1.1	−3.0[b]	1.2	−3.4[b]	−1.2	−4.3[b]

. . . and analysis by modal grade shows similar pattern of gains, declines in lowest and highest achievement classes

	Age 9 4th Graders		Age 13 8th Graders		Age 17 11th Graders	
Change[a]	Lowest	Highest	Lowest	Highest	Lowest	Highest
Reading	6.1%[b]	1.4%[b]	1.7%[b]	0.4%	−0.[illegible]%	−0.5%
Science	1.4[b]	−2.4[b]	1.7[b]	−2.5[b]	0.[illegible]	−4.2[b]
Mathematics	0.4	−3.1[b]	1.1	−3.4[b]	−1.[illegible]	−4.3[b]

[a] National mean percentages of changes in performance. [b] Statistically significant, as defined by standard convention whereby differences between statistics are designated as significant only if the differences are at least twice as large as their standard errors.

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quartiles of low achievers, mid-low achievers, mid-high achievers, and high achievers. This analysis provides additional insight into achievement, since both black and white students, for example, are in all of the achievement classes.

The modal grade is the grade in which the majority of students of a particular age are enrolled—the fourth grade for nine-year-olds, the eighth grade for 13-year-olds, and the 11th grade for 17-year-olds. NAEP points out that modal grade data are especially useful when juxtaposed with national data for age populations and the reporting groups within them. For example, age data indicate that certain groups—Hispanics, blacks, those attending school in disadvantaged urban communities, and several others—tend to perform at levels below the national average in reading, science, and mathematics. However, a disproportionate number of these students are found below modal grade as well.

Analysis of the data by achievement class shows that although low achievers by definition do not do as well as high achievers, the gap between them appears to be narrowing. In reading, both low and high achievers at age nine improved significantly. Among 13-year-olds, less able students scored higher in reading than those assessed five years earlier, while academically adept students showed no change. Neither high nor low achievers at the senior high level showed any significant changes in their reading skills.

Mathematics and science performance of students in the bottom quartile did not change between assessments, with the exception of 13-year-olds, who improved in science. However, the mathematics and science skills of high achievers at all three ages declined.

Analysis by modal grade and group (black and white) shows that among both low and high achievers, black students in the modal grade were more likely than white students in the same grade to show gains, although overall performance of black students remained below that of their white counterparts. More specifically:

- Black low achievers in the modal grade for their age group improved in reading at ages nine and 13 and improved in mathematics and remained stable in science at all three ages.
- White low achievers in the fourth and eighth grades improved significantly in reading and science and held their own in mathematics. But the performance of less academically inclined 17-year-olds in the 11th grade declined in reading and mathematics.
- Black high achievers at grade level for their age registered gains in reading and mathematics at age nine and in reading at age 13. However, mathematics skills for both 13- and 17-year-olds declined, as did science abilities at age 17.
- White high achievers in grades four, eight, and 11 did not improve in any of the three subjects. They maintained the status quo in reading, but mathematics and science performance declined significantly at all three ages.

NAEP convened a panel of experts in education and social trends to explore why these results had occurred. Some observations by the group are that compensatory education programs flourished in the 1970s, partly as a result of federal initiatives. At the same time, support for science programs dwindled, and mathematics didn't get the emphasis reading did. Moreover, teachers in these subjects were in increasingly short supply. And high school graduation requirements in both science and mathematics were relaxed. Finally, the popular back-to-basics movement often focused on lower-level skills, perhaps at the expense of a challenge for more able learners. ☐

SCIENCE

Syringe pump injects hormones periodically

A difficulty associated with the care of hormone-deficient patients is that treatment usually calls for repeated injections at regular intervals. A new device engineered at the U.K.'s Medical Research Council overcomes that problem.

It consists of a pump that exerts pressure on the plunger of a syringe at preset times. A specific quantity of hormone-containing solution is forced through a narrow plastic tube, the tip of which is embedded under the patient's skin. The lightweight unit is about the size of a packet of king-size cigarettes. It usually is strapped to the upper arm, and the wearer is hardly aware of it.

The device, which is not yet commercially available, is the brainchild of Howard Jacobs, a research endocrinologist at London's Middlesex Hospital. "At present we are using it for women who can't ovulate because there is something wrong with the hormones that drive the ovaries," he says.

He and his patients are delighted with the results. A number of women who were thought to be infertile became pregnant, and several births have resulted.

In some cases, infertility in women stems from lack of pituitary gonadotrophic hormones—follicle-stimulating hormone and luteinizing hormone—normally secreted in response to specific hormone-releasing factors from the neighboring hypothalamus. Previously, the condition has been treated with clomiphene. This analogue of chlorotrianisene, a nonsteroidal estrogen, stimulates increased secretion of the pituitary gonadotrophins by blocking the negative feedback receptor sites in the hypothalamus. But multiple ovulation, with multiple pregnancy, can occur.

With the new pumping unit, gonadotrophins are injected 16 times a day, "which is actually what is needed for this kind of treatment," Jacobs notes. And because administration can be controlled with precision, multiple pregnancies should be eliminated.

Jacobs and his team are testing the units with a group of infertile men who have a similar hormonal problem.

Children with hormone-related puberty problems also could benefit from the treatment. ☐

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CHEMICAL & ENGINEERING NEWS

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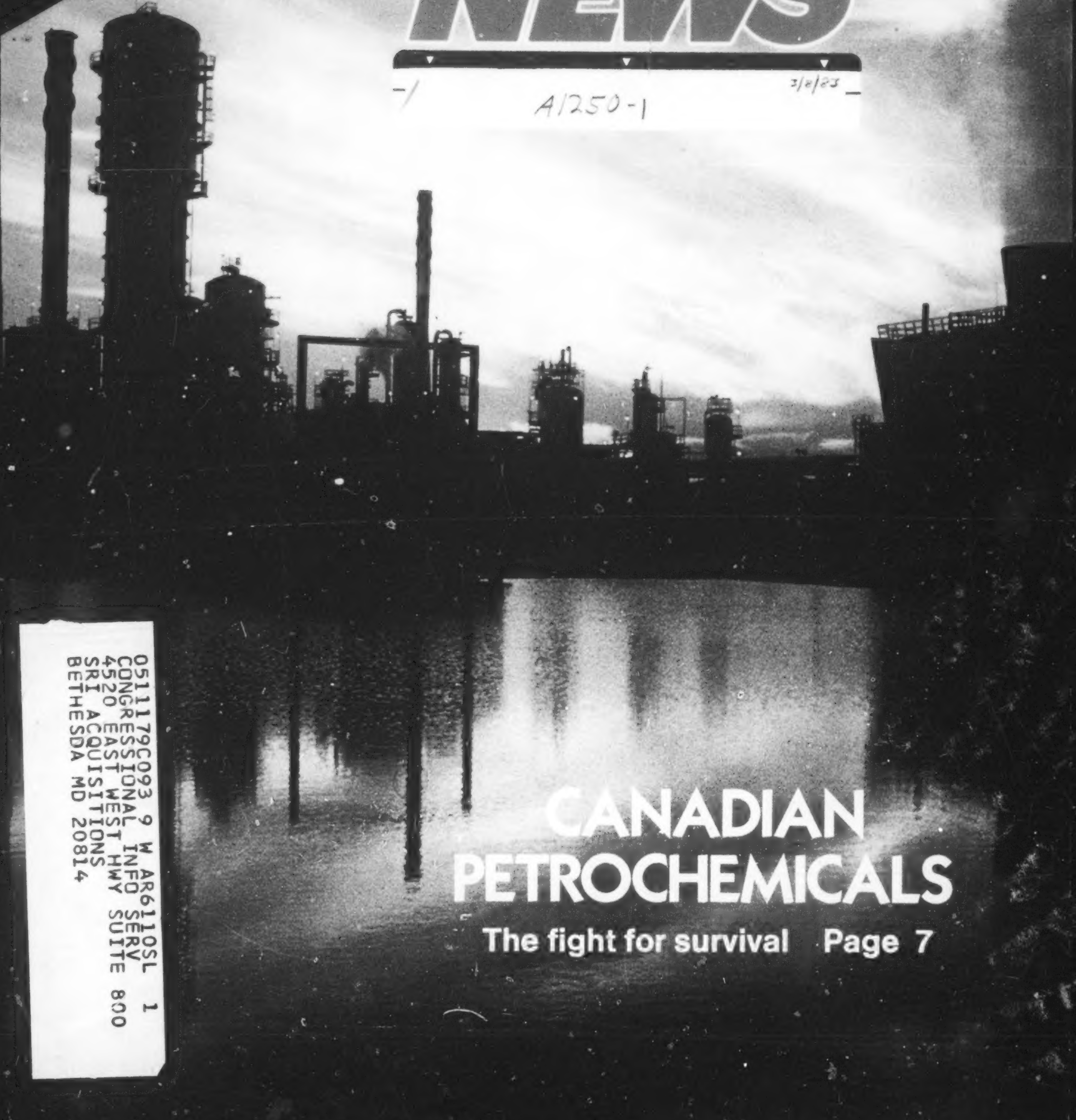

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CANADIAN PETROCHEMICALS

The fight for survival Page 7

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Cover: Styrene plant at Sarnia, Ont., recently completed by Canadian Badger (part of U.S. Badger) for Polysar

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Business

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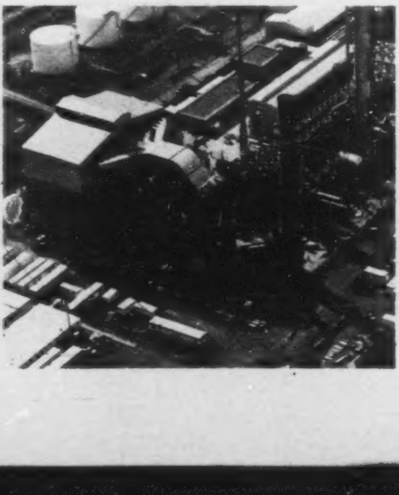


News Focus

After a spate of new plants in the 1970s, Canada's once-promising petrochemical industry now is fighting for survival. **Page 7**

Canadian Petrochemicals: Great Opportunity Has Turned Sour

It's East vs. West and oil vs. natural gas as federal government tries to determine how it can help once promising, but now ailing, petrochemical industry

Earl V. Anderson, C&EN New York

Very soon, Chem Systems, the Tarrytown, N.Y.-based consulting firm, will launch a major multiclient study on the petrochemical industry of Canada. That it should choose the Canadian petrochemical industry as a subject hardly comes as a surprise. Many observers of the world petrochemical scene are wondering in amazement just what has happened to bring Canada's once-promising petrochemical industry to its knees and whether the industry will be able to regain the potential that everyone seemed certain it could attain.

The answer to the first question is complex, but there to decipher. It involves an unfortunate (for Canadian petrochemical producers) national energy pricing policy and even more unfortunate timing that brought a domestic and worldwide recession and falling world energy prices into play with it.

Exports, in vessels such as this Dow Chemical Canada tanker, are important but now weakened outlet for Canadian chemicals

The answer to the second question has not yet surfaced, though it may very soon. But when it does, it will rise out of federal government offices in Ottawa, and perhaps from some provincial capital, more so than out of the industry itself.

The reason is simple enough. It was, in large measure, government policy on energy prices that helped push the Canadian petrochemical industry into trouble. It may take a revamped energy pricing policy to pull it out.

Canada, of course, is a hydrocarbon-rich country, one of the very few among industrialized countries. After years of lying dormant, the country's small, inefficient petrochemical industry sprang to life in the mid- and late seventies. Lured by plentiful and inexpensive natural gas in Alberta, the industry launched a major round of world-scale plant building in the province.

In western Canada, the emphasis was on ethane-based ethylene, its derivatives, and methanol. However, other ambitious projects were put into brick and mortar or planned by the established, oil-based segment of the industry in the eastern petrochemical centers of Sarnia, Ont., and Montreal, Que.

With a population of only 27 million, roughly one

Petrochemical investment in Eastern Canada totals $3 billion

	$ Million (Canadian)		$ Million (Canadian)
Dow Chemical	$150	**Polysar**	$ 600
Du Pont	350	**Shell**	300
Esso	200	**Union Carbide**	350
Hercules	50	**Other**	250
Petromont	50	**TOTAL**	**$3000**
Petrosar	700		

Note: Investment is in Sarnia, Ont., and Montreal, Que., areas. **Source:** Union Carbide Canada

tenth that of the U.S., only one world-scale plant could service the domestic Canadian market for most major petrochemical products. But Canadian petrochemical companies, most of which are subsidiaries of multinational companies with established, worldwide marketing networks, have their eyes on export markets.

As recently as two years ago, Canadian companies talked confidently about a "window of opportunity" through which they could leap to world petrochemical prominence. By moving swiftly, they could capture markets made available as hydrocarbon-poor countries such as Japan cut petrochemical capacity and before potential competitors such as Saudi Arabia and Mexico could launch their own assaults on the world marketplace. The scenario, especially in view of Canada's advantage in feedstock pricing, seemed unassailable.

Last year, however, it became painfully apparent just how tenuous that scenario was. Virtually all Canadian companies involved in petrochemicals lost money—a lot of money. A couple of them have edged dangerously close to financial disaster.

Production was off considerably last year. Sales were down. Exports suffered.

Plant operating rates were uncomfortably low. Scheduled plant shutdowns were extended and other plants simply shut down for lack of demand.

Layoffs were commonplace throughout the industry. Many capital spending projects were delayed, canceled, or scaled back.

Reeling from these blows, the industry has turned, as many Canadian companies are prone to do, to the government for relief and aid. More specifically, a group of oil-based petrochemical companies in eastern Canada has mounted a highly visible campaign to obtain government assistance in solving their problems.

This in itself has complicated Canada's petrochemical future. The industry is badly divided on the issue. Western gas-based producers sharply disagree with their eastern cousins about the type of aid that is needed; indeed, whether any aid is needed at all.

In part, these differences reflect traditional provincial jealousies that have long existed in Canada. But only in part. Mostly, they reflect the different strengths and weaknesses that each faction perceives itself to have.

Even in the East, not all petrochemical companies think that government assistance is necessary. The group that is petitioning Ottawa for help is led by Petrosar Ltd. and Petromont Inc. and includes six other companies that are either their owners, their customers, or both. Petrosar operates the petrochemical core complex around which Sarnia's "chemical valley" is built. Petromont fills that same role in the Montreal area.

This dichotomy in the industry's attitude about what is and what is not necessary to get back on its feet, unquestionably is making an already difficult search for a solution even more difficult. That search really started last spring when a government task force was formed to look into the problems of Canada's petrochemical industry.

The task force completed its report last fall. It was, according to one participant, an "analytical job" designed to "give the ministries certain options that they had for action, including no action."

It was a "factual" report and contained no recommendations. It also has been kept highly confidential.

Since then, the government's chemical experts have been conferring with the ministries involved, revising and updating their information and making recommendations. Again, very little has leaked out about these proceedings.

About all that one participant will say is that "the ministers are giving the situation priority consideration. Their decision is imminent."

Indeed, it may be very imminent. Industry leaders have been expecting something to break for weeks now.

Whatever it is that the ministers decide to do—or not do—their decision will play an important role in shaping the future of Canada's petrochemical industry. This isn't really startling; it has been the government's policies, especially those dealing with energy pricing, that have helped shape industry developments over the past several years and have helped to put the industry in its present predicament.

Canada's hydrocarbon resources are the envy of many less-endowed industrial countries. Oil and gas producers, primarily in Alberta, have supplied about 75% of Canada's oil requirements. Some eastern provinces rely on imported crude because pipelines aren't available to carry western Canada crude to them.

In addition, western gas producers supply all of Canada's natural gas requirements, with more than enough left over to export about a third of their production to the U.S. Reserves of natural gas are increasing. These resources, along with a policy that has kept prices down, has created an attractive climate for petrochemical investment.

In 1978, Petrosar came on stream with its petrochemical refinery near Sarnia. It included a crude oil topping unit and a naphtha cracker capable of producing 1 billion lb per year of ethylene, 725 million lb of propylene, and lesser amounts of C-4s and aromatics.

Petrosar is a joint venture owned by Polysar Ltd. (40%), Du Pont Canada (20%), Union Carbide Canada (20%), and Canada Development Corp. (20%). Petrosar supplies raw material that its chemical company owners need to run their nearby derivatives plants.

In 1979, Alberta Gas Ethylene started the petrochemical ball rolling in Alberta with its first ethylene plant (AGE I), a 1200 million lb-per-year unit at Red Deer. In two short years, Canada's ethylene capacity leaped from just over 1 billion lb to 3.25 billion lb.

A year later, in Montreal, two area chemical companies formed Petromont in an effort to consolidate their petrochemical base. Gulf Canada and Union Carbide Canada each own one third of Petromont. The other third is owned by the province of Quebec through its holding company, Société Generale de Financement (SGF).

Petromont is the nucleus of the Montreal area petrochemical industry. It has a 55,000-metric-ton ethylene plant in Montreal East and a 225,000-metric-ton unit at Varennes. With an eye toward future petrochemical development in the area, Petromont has sketched plans to double capacity at Varennes.

Hard on the heels of this start, a flood of new plant announcements poured out of Canada. Some projects were slated for the East, but most were earmarked for the West.

Alberta Gas Ethylene launched its second world-scale ethylene project (AGE II) with a capacity of 1.5 billion lb. The company started planning for AGE III, another 1.5 billion lb ethylene unit. Meanwhile, Esso Chemical, Alberta Energy Co., and Hudson's Bay Oil & Gas planned a 1.5 billion lb ethylene plant of their own at Redwater, Alta.

Producers of ethylene derivatives launched their own projects and battled to capture a share of the ethylene that was to come. In addition, benzene, styrene, methanol, ammonia, and urea projects were unfurled in Alberta.

For plants coming on stream in the province between 1981 and 1986, the estimated tab exceeds $5 billion (Canadian dollars throughout the article).

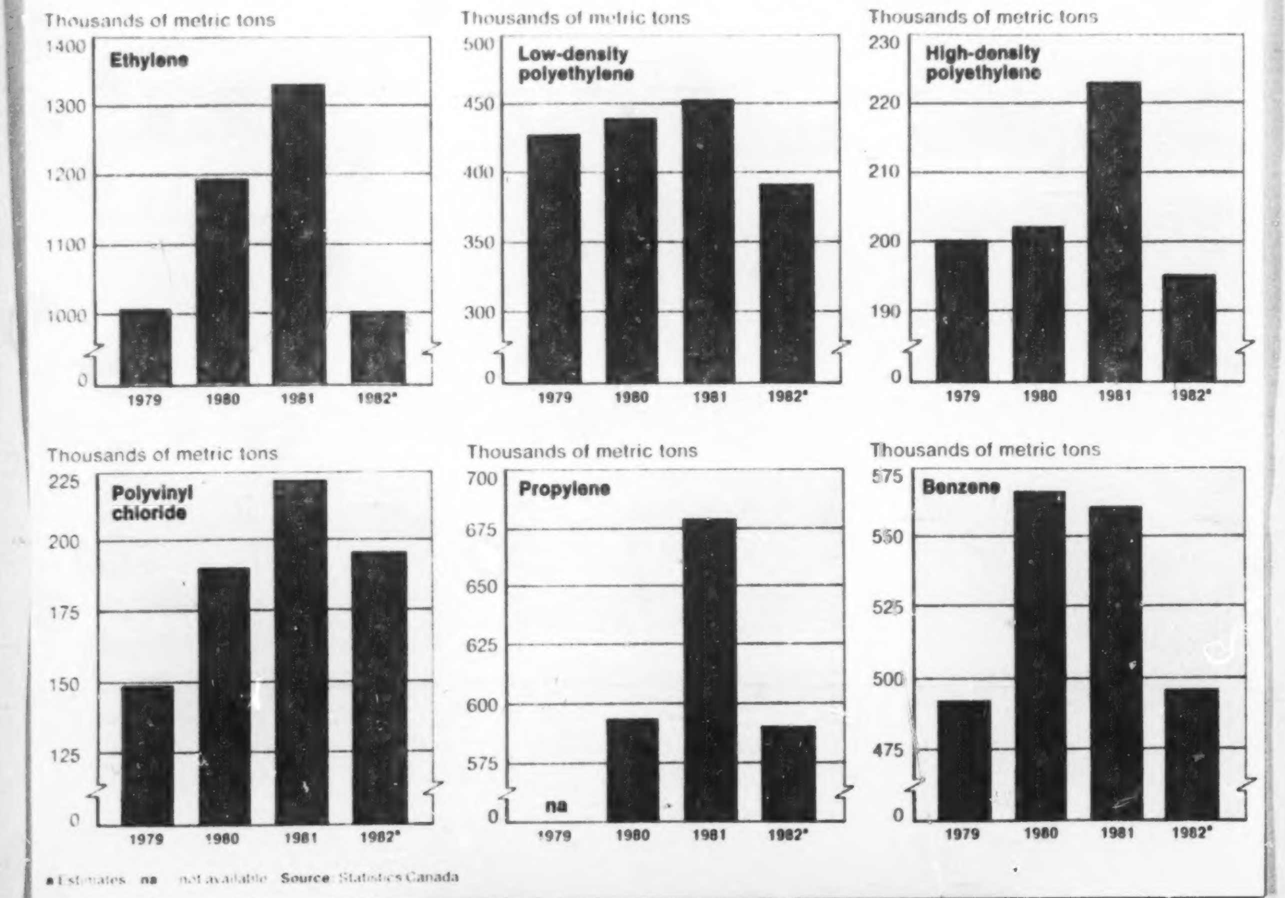
Enthusiastic petrochemical planners, confident that they could turn loose all of their output on the export markets, didn't anticipate what was going to happen in Canadian energy politics.

Agreements that set oil and gas prices in the late 1970s expired in early 1980. Taking their place was Canada's highly controversial National Energy Program (NEP).

NEP was born at a time when Canada was using more oil than it was finding. Natural gas reserves, however, were mounting. The new energy program reflected this by promoting natural gas at the expense of oil.

For petrochemicals specifically, NEP stipulated that

Production of most major petrochemicals dropped in Canada last year



* Estimates na not available Source: Statistics Canada

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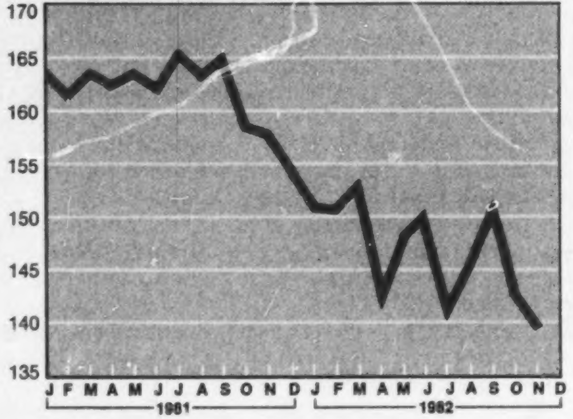
Canadian chemical output has fallen off sharply

Index of gross domestic product[a]



[a] Chemical and chemical product industries, seasonally adjusted, 1971 = 100. **Source:** Statistics Canada

no additional volumes of oil were to be used to support future industry growth. This came as a blow to oil-based producers in the East. However, it stated that Canadian prices never would exceed 85% of the world price or the average U.S. price, whichever was lower. Natural gas prices were set at 65% of crude prices.

At the time, it appeared that NEP guaranteed Canadian petrochemical producers a feedstock advantage. That didn't last long. Alberta, dissatisfied with the low prices that it was receiving for a depleting resource, forced a new pricing policy out of Ottawa. It doesn't mention an 85% ceiling.

Policy makers, blindly anticipating ever-rising world oil prices like many others at the time, assumed that the 85% ceiling would not be breached. The new agreement called for a rigid, inflexible schedule of price hikes for Canadian oil.

The Canadian petrochemical industry, says C. L. (Cliff) Mort, former chairman of Dow Chemical Canada and now a consultant, "was asleep at the switch." Mort says that he detected very little dissatisfaction with energy prices.

It wasn't long before dissatisfaction set in. Starting in mid-1981, and even more dramatically last year, Canada's petrochemical fortunes plummeted. André G. Lapalme, vice president and general manager of hydrocarbons for Union Carbide Canada, says, "We now are fighting for survival."

Like other industries, the Canadian petrochemical industry had to contend with recession, both at home and in its major foreign markets. It also had another cross to bear. While feedstock costs throughout the world were tumbling, especially along the U.S. Gulf Coast, they were rising in Canada.

In a recent update of a brief prepared by eastern producers for the government, it is estimated that the blended oil price at Montreal last September was 89.9% of the average U.S. price. This month, it's estimated to rise to 98.3%. Both are well above the 85% ceiling promised by NEP.

Squeezed by sagging markets and rising feedstock costs, Canada's chemical companies took a financial beating last year. Combined sales of four companies charted by C&EN (C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada) fell 12.5%. More important, these companies lost $15.7 million on those sales.

Canadian chemical exports also fell—11.6% to just over $4 billion. Carbide's exports were off by a third and Du Pont's were down 21%, indications of just how much the industry's competitive edge was dulled.

Operating rates, employment, and investment plans were scaled back. Permanent plant shutdowns loomed as a definite possibility.

In Alberta, the AGE II ethylene project is proceeding on schedule, but derivative plants will be able to take only two thirds of its capacity by 1985. Meanwhile, AGE III and the Esso-Alberta Energy ethylene plant have been postponed indefinitely. Observers doubt if the fourth ethylene unit will ever be built.

Canadian ethylene capacity, once forecast to hit 9 billion lb by 1987, now is pegged at only 4.6 billion lb. Present capacity is 3.4 billion lb.

In the East, some companies face the possibility of folding. Petromont and Petrosar are in big financial trouble.

Petromont's expansion ambitions have been scrubbed. Serge Guerin, Petromont's assistant to the president, says that the company could shut down soon if it doesn't get a prompt, $30 million shot in the arm.

In Sarnia, Petrosar president Charles Ambridge concedes that company losses last year were "in the tens of millions of dollars." Petrosar claims that it has no intention of closing down, but outside observers openly wonder how long it can last without government assistance. In 1986, a government-held debenture of $350 million becomes due.

Government help is exactly what Petromont and Petrosar are seeking. Detractors say that they want a handout or bailout. Eastern companies maintain that they are after relief and incentives.

Whatever it's called, Petromont, Petrosar, and six other eastern companies (BASF Canada, Du Pont Canada, Hercules Canada, Polysar, Société Generale de Financement, and Union Carbide Canada) presented Ottawa with a brief last October outlining their problems and possible solutions.

The eight companies insist that long-term prospects for petrochemicals in Montreal and Sarnia are promising. At stake is survival over the short term. They want Ottawa to act, and act fast.

Their problem is twofold: the recession with its weak markets, and high feedstock costs. The recession they can do nothing about, but they believe that something can and should be done about feedstock costs, which account for 60 to 75% of total product costs.

They emphasize that a heavy tax burden on crude oil is a major cause of their high feedstock costs. Of the roughly $35 per barrel for Canadian blended crude, more than $27, or 78%, goes into federal and provincial

Eastern petrochemical producers think their oil is too expensive

Eight petrochemical companies in eastern Canada, whose raw materials depend on crude oil-based feedstocks, have petitioned the government for immediate short-term relief, especially relief from up-front taxes on crude oil and a long-term feedstock policy distinct from energy policy.

These companies—BASF Canada, Du Pont Canada, Hercules Canada, Petromont, Petrosar, Polysar, Société Generale de Financement, and Union Carbide Canada—claim that the heavy dose of up-front taxes and a rigid schedule of price increases have eroded the price advantage that they thought they had received under Canada's National Energy Program (NEP) of 1980. NEP states that "the blended price of oil (old, new, and synthetic oil) will never exceed 85% of the international price or the average price of oil in the United States, whichever is lower."

NEP authors, however, never reckoned with falling world crude prices. Now, eastern petrochemical producers claim that, as a result of falling world prices and increasing Canadian prices, they have lost their all-important feedstock advantage.

Here's how these producers figure what it's costing them for their crude. Taxes, both federal and provincial, account for about 78% of the total.

	Actual Sept. 1982	Estimated March 1983
	($ per bbl, Canadian)	
Producer	$ 5.95	$ 6.87
Alberta royalty	9.76	11.28
Petroleum and gas revenue tax	2.53	2.92
Federal income tax	6.16	7.12
Alberta income tax	1.35	1.56
Incremental oil revenue tax	0	0
Wellhead price of old oil	**$25.75**	**$29.75**
Petroleum compensation charge	6.30	3.76
Canadian ownership special charge	1.15	1.15
Transportation (to Montreal)	1.67	1.74
BLENDED PRICE AT MONTREAL	**$34.87**	**$36.40**

As a result of the fixed-schedule price increases and the heavy tax burden, eastern petrochemical companies claim that their oil costs already exceed the 85% limit promised by NEP.

The calculations below were made before the most recent round of price cuts in world oil. With them, eastern petrochemical producers may end up paying more for their oil than the prices on either the world or U.S. markets.

	Actual Sept. 1982	Estimated March 1983
	($ per bbl, Canadian)	
Blended price at Montreal	$34.87	$36.40
International price (landed at Montreal)	40.94	39.71
International price (quality adjusted)	41.75	40.52
Average U.S. price	38.78	37.04
Blended price ratio		
vs. actual international	85.2%	91.7%
vs. quality-adjusted international	83.5%	89.8%
vs. U.S. price	89.9%	98.3%

Source: Report, "Problems of the Petrochemical Industry in Ontario and Quebec. Update" (Feb. 4, 1983)

coffers. Producers receive only $5.95. If world prices for oil continue to go down, the competitive position of eastern chemical companies will deteriorate even further.

What the eight companies recommend is a three-part fix:

- A short-term relief mechanism.
- A petrochemical feedstock policy for the long term that distinguishes between feedstock and other uses of oil and gas.
- Enough flexibility and pricing controls in that feedstock policy to enable the eastern oil-based industry to remain competitive with its western, gas-based counterpart.

Specifically, the companies want an immediate exemption from the petroleum compensation charge and the Canadian ownership special charge for all oil that is upgraded into petrochemicals. This would cost the government about $125 million per year.

As part of long-term feedstock policy, they suggest placing a cap on feedstock prices just as NEP intended to do with oil. However, they want enough flexibility in setting that cap to contend with changing world competitive conditions.

Eastern producers believe that they can adapt their plants to use a more varied mix of feedstock, including the liquefied petroleum gases propane and butane. Indeed, they want to, but only if LPGs are priced competitively with natural gas.

That's because eastern producers are looking in two directions at the same time. They want to be internationally competitive, but they also want competitive equality with western gas-based producers. Indexing natural gas at 65% of crude, they argue, was done for energy reasons, not to promote a petrochemcal industry in Alberta at the expense of the East.

By competitive LPG prices, of course, the eight companies mean lower prices. Export prices, relatively high and profitable for LPG producers, set the price in Canada. In effect, they establish a floor under domestic prices that eastern companies consider too high.

In addition, the Natural Gas & Gas Liquids Tax (NGGLT), which is levied on propane and butane but, significantly, not on ethane, lifts the LPG floor even higher. As a result, eastern producers say that LPG prices are too high for them to consider.

What they would like to see is the LPG price floor lowered by a combination of export restrictions that would drive the price down in Canada, and NGGLT eliminated to drive it down even more.

Add to that some federal aid in the investments needed to build delivery and storage facilities, and eastern petrochemical producers would be willing to modify their plants to handle LPG.

The eight companies have backed up their proposals with some powerful arguments. They emphasize, for instance, the importance of coproducts available from naphtha cracking that aren't available from ethane-based ethylene plants. Propylene and C-4s are important to eastern downstream companies, especially C-4s for Polysar's rubber operations.

They argue that, even if someone wanted to develop an oil-based industry in Alberta where the oil is, high distribution costs to eastern markets would make it an unprofitable proposition. And, says the eastern contingent, even if they convert partially to LPG, they still would be able to meet eastern coproduct requirements.

Other arguments are certain to set politicians to thinking. The eight companies have developed figures that indicate, without relief, about 54,000 jobs would be in jeopardy, either in the industry directly, or in downstream and consumer industries. With unemployment high in Canada, that's hard for politicians to ignore.

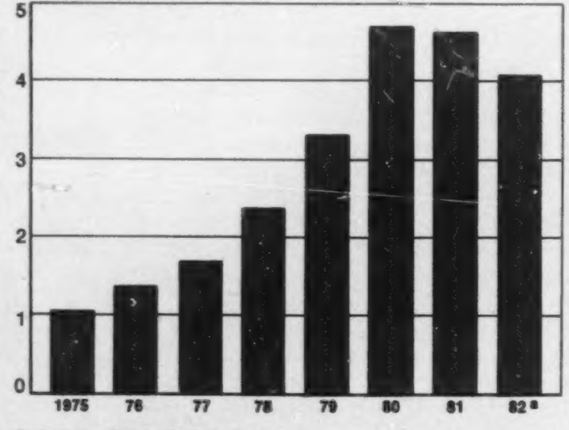
If the eastern industry gets its relief, the government would receive an additional $385 million in personal and corporate income taxes and savings in unemployment payments. Without relief, it would lose $800 million.

Canada's balance of trade also would suffer. Given relief, eastern chemical companies could help boost the trade balance $1.5 billion. Without it, the trade balance would drop a hefty $3 billion because of lost export opportunities and increased imports.

Unlike the eastern companies, which have gone public in a big way with their side of the story, western companies have been noticeably silent. That soon may change.

"Eastern companies weren't the only ones hurt last year," says John E. Feick, senior vice president for Novacor Chemicals. At one point, ethane prices were 25% higher in Alberta than they were on the Gulf Coast. The operating rate for AGE I averaged only 55% in 1982. The gas-based industry in western Canada lost about $70 million last year, according to Feick. Despite this, western producers are reluctant to complain or to ask the government for assistance.

Exports of Canadian chemicals slipped in 1982



a Preliminary. **Source:** Statistics Canada

The western industry is confident that, over the long haul, it can regain its competitive edge over U.S. producers, who are its primary competition.

Dow Chemical Canada, which has a foot in both camps, thinks that the present situation is a short-term phenomenon for western companies. Says board chairman James M. Hay, "We should let the market resolve our problem."

Western producers particularly resent any assistance that might be supplied specifically to Petromont and Petrosar. "That," says Feick, "will alter the natural competitive battle between liquids in the East and gas in the West."

The West, including gas companies and the Alberta government, is irritated by eastern proposals to equalize gas costs across Canada and to restrict LPG exports. And it is concerned that government attempts to help eastern producers will be viewed by other countries as an illegal subsidy, subject to countervailing duties. This could hurt western chemical companies, which are heavily export oriented.

The eight eastern companies discount this argument, but it can't be brushed aside. The federal government also is concerned about creating another potential Canada-U.S. trade problem.

East-West feuds are nothing new in Canada, so it is not surprising that the West doesn't want to see federal funds go to support jobs in the East that eventually could end up in Alberta.

All of this leaves Ottawa between a rock and a hard place; in fact between several rocks and several hard places. It faces another East-West confrontation, an oil-vs.-natural gas battle, and it is caught between a desire to save jobs and a shortage of money to do much about it.

No doubt the task force report painted a bleak picture of the outlook for eastern petrochemicals. But Ottawa watchers believe that, unless the ministers involved change their present line of thinking, no large-scale bailout is likely.

They see little hope that the government will suspend the up-front taxes on oil for petrochemicals. Other industries would scream for similar treatment. It also would irritate Alberta and reverse NEP policy of encouraging gas substitution for oil.

Best guesses are that Ottawa will provide some special assistance for Petromont, if only because politically powerful Quebec is forcing the issue. The jury is still out on what Petrosar may get.

Whatever does come out of Ottawa will be a political decision as much as a business decision. That decision, tough as it is, could come very soon.

Says one Canadian chemical expert, "It would help if the industry closed ranks with one point of view. The real competition lies beyond the Canadian borders."

But that closing of ranks is unlikely to happen. □

Flame Retardants in Plastics: Growth Depends on Regulation

While they wait for the government to act, producers of flame retardants focus on high-technology uses and better performance

David Webber, C&EN New York

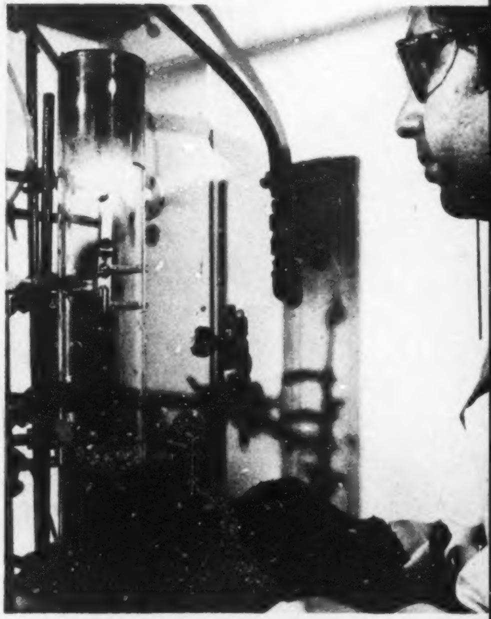
The federal government has been wielding regulation like a rod of discipline over the chemical industry for so many years now, most chemical producers find it difficult to think of agency action toward them as anything but a scourge. But to the producers of flame-retardant chemicals used in plastics, the government's big stick looks more like a magic wand.

Stricter federal fire safety standards for materials used in construction and furniture could increase the market for many types of flame retardants hundreds of percentage points almost overnight. There is only one problem. The government has to wave that wand. And flame-retardant producers, made distrustful of the federal regulatory bodies by their history of sudden policy reversals and slow action on fire safety, fear it won't happen.

The shock of the string of notorious fires that have taken place in the past few years in the U.S. raised expectations in many people that the federal government finally would be pushed, as it often is by human catastrophe, into undertaking the task of creating new fire-safety standards. The main focus of the new strictures, citizens' groups demanded, should be plastic and urethane foam furnishings, because the fumes produced by the combustion of the many synthetic materials commonly used today frequently have been blamed—as yet without conclusive scientific proof—for causing more deaths than are caused by flames, heat, or the fumes emitted by natural materials.

For the most part, however, the new standards have not appeared. California, regularly a leader in consumer-oriented laws, has unilaterally imposed tougher flammability standards on furniture upholstered with flexible urethane foam. And the state of New York has appointed a special commission to study the scientifically labyrinthine problem of products of combustion toxicity. Elsewhere, on the state and local levels, committees have formed to deal with the same question, and everywhere consumer advocates have fulminated unceasingly against the perils they see in burning synthetic materials.

At the federal level, however, attempts to create laws or regulations on fire safety have fizzled like so many matches held up to wet wood. The Consumer Product Safety Commission, for instance, which many expected to regulate the flexible foam furniture industry, has agreed instead to allow the Upholstered Furniture Action Council, a body representing seven furniture trade associations, to carry out a protracted program of testing and research aimed at developing voluntary industry standards for fire safety. That policy is in line with the Reagan Administration's broad movement away from government regulation. But consumer advocates complain that the Action Council's program, which still seems a long way from fruition, has been marked more by inaction than anything else.

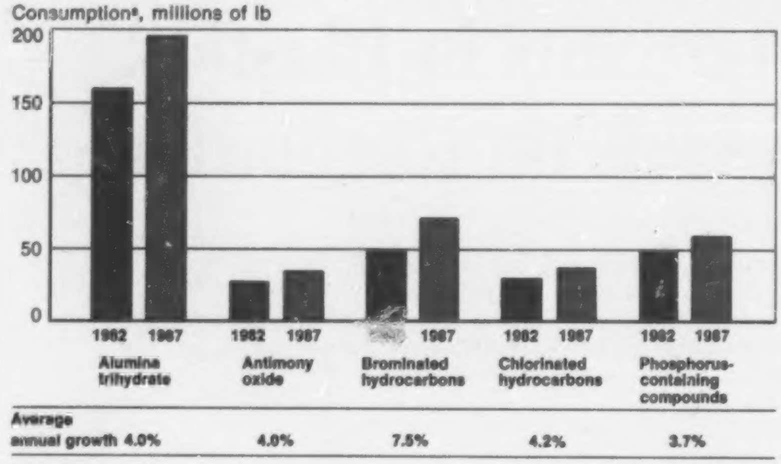

An experimental flame retardant for plastics is tested by PPG Industries research chemist Ash Jagtap

"With the current regulatory climate, we don't foresee national regulations that would result in a big boon for us," comments Harold James, market manager for flexible urethane at Olin Corp., which produces a chlorinated phosphate flame-retardant additive for flexible foam.

Nor do most other flame-retardant chemical producers. Instead, they must market their chemicals on the basis of their potential customers' self-interest. The addition of flame-retardant chemicals to compounded plastic and foam products where it is not required, the sales pitch goes, can reduce exposure to product liability, and consequently enhance the image—and value—of the customer's product.

"One thing that's helping keep the fire safety of materials in the limelight is insurance costs," remarks Charles T. Ludwig, director of marketing of flame retardants at Great

Use of most major flame retardants is growing slowly



a Estimates.

Lakes Chemical, the leading producer of brominated flame-retardant chemicals. "People like Factory Mutual are getting in and saying, 'Hey, we've got a real responsibility, and even though it may not be legislated, if you do this and this and this, it will help to reduce your insurance cost.' "

In addition, since government standards are probably inevitable, the voluntary adoption of high levels of flame retardancy by manufacturers now may spare them from the kind of best-available-technology standards that plague the chemical industry's pollution control efforts. Although the approach and motives of all parties involved are somewhat different, both flame-retardant chemical producers and manufacturers of products that use synthetic materials are promoting a performance approach to fire safety. They hope that by coming up with systems—combinations of flame-retardant chemicals and structural modifications—for products like furniture that are substantially harder to ignite and, if burning, give off less smoke, they will keep the federal wolf out of the fold.

At the same time, however, flame-retardant chemical producers often are stymied by factors that convince many plastics compounders to wait until the government forces them to raise the fire safety of their products. Flame-retardant chemicals cost money, an obvious fact that discourages managers trying to improve profitability as industry begins its recovery from recession. Why add chemicals that cost an average $1.50 per lb, many production managers ask, when the only immediate commercial value will be to enhance the product's image, a financially unquantifiable achievement.

But even more crushing to many a flame-retardant chemical salesman's argument is the technical objection: The majority of these compounds are additives that do not join in the molecular structure of the plastic being treated. As a result, all resins mixed with flame-retardant additives sacrifice something in the way of performance or appearance or both. Often, as well, there are problems with processing and damage to plant equipment. Finally, the greater propensity of additive rather than reactive chemicals to leach out of the substrate complicates questions of toxicity.

These problems and the fact that the two biggest markets for flame-retardant chemicals—polyvinyl chloride (PVC) and polyurethanes—depend ultimately on the recession-sensitive automobile and housing industries combined to reduce sales last year and to produce predictions for many flame-retardant chemicals of growth at only the rate of the gross national product over the next five years. The only remarkable recent growth has come, and probably will continue to come, in the high-technology electrical/electronics sector, dominated by printed circuit boards, business machines, other electric appliances, and wire and cable applications. This shift in the market favors the flame-retardant chemicals that treat thermosets such as epoxy resins, and engineering thermoplastics such as high-impact polystyrene and polyphenylene oxide.

Consequently, bromine compounds have become the most vital part of the flame-retardants business in recent years. The major flame-retardant chemical for epoxy resins, for instance, is tetrabromobisphenol-A (TBBPA), used extensively in printed circuit boards. The only U.S. producers have been Great Lakes Chemical and Dow Chemical. But Ethyl Corp.'s Saytech subsidiary, whose announced goal is to wrest the lead from Great Lakes, is building a 15 million lb-per-year TBBPA plant in Magnolia, Ark., scheduled to come on stream next January. Saytech also has intensified competition in the market for decabromodiphenyl oxide (decabrom), used primarily in high-impact polystyrene (most of which goes into television set bodies), by bringing on a new unit last December in Magnolia that will have an ultimate nameplate capacity of 10 million lb per year. The facility has greater flexibility than Saytech's previous decabrom plant in Sayreville, N.J., which now will be diverted into other product lines. The other producers of decabrom are Great Lakes and White Chemical. The market for flame-retardant treatment of acrylonitrile-butadiene-styrene (ABS) is overwhelmingly dominated by Great Lakes with its octabromodiphenyl oxide and other products.

Producers of brominated flame retardants foresee overall average annual growth for their products of about 7.5% over the next five years. Those products used in epoxy, says James D. Innes, vice president of marketing and sales at Saytech, are mostly TBBPA and will grow 8 to 9% per year. Sales of decabrom, he predicts, will increase at an average annual rate of 7 to 9% between 1982 and 1987.

But high-impact polystyrene and ABS, big users of bromine compounds, do not own the increasingly important business machine and appliance sector. Modified polyphenylene oxide (PPO), which challenges in many areas, is flame-retardant-treated with nonhalogenated phosphate esters. Use of modified PPO, produced by General Electric, Borg Warner, and others, recently has been spurred, some sources say, by pressure applied by GE. GE makes a broad range of high-technology products used in the business machines sector.

Still, for producers of nonhalogenated phosphate ester flame retardants, sales to makers of modified PPO have been no more than a small bright spot. About 75% of these flame-retardant chemicals go into flexible PVC, which was hurt by last year's sharp decline in construction. Even though housing starts are rising now, nonhalogenated flame-retardant chemical producers worry that fears of smoke and toxic fumes from PVC furnishings will dampen the market for flexible PVC in coming years, taking the edge off the economic recovery. The market is described as essentially mature; anticipated five-year growth likely will average no more than 3 to 4%.

"Competing products are more economical," says one producer resignedly. "Customers only use phosphate esters when they have to, when they can't find a substitute."

Nor have recent years been kind to halogenated phosphorus-based flame retardants, the great majority of which are used in urethane foams. Not only did the recession in housing construction hurt sales, but the continued lack of fire safety regulations have their greatest impact in this market. The only standard on flexible polyurethane foam furniture on the books today is California's Bulletin 117. (Automobile seat cushions are controlled by the Department of Transportation's Motor Vehicle Safety Standards, and other agencies regulate foam flammability performance in other smaller business sectors.)

As a result, not only is business expected to grow no more quickly than GNP, lack of optimism has sapped producers' enthusiasm for the development of new products and aggressive marketing. "We don't have a whole lot of faith in future regulations," comments Olin's James, "so we're no great shakes in R&D. We're not planning anything new now."

As James explains it, foam producers who are not required by law to use flame retardants have no incentive to do so. The only exception is combustion modified, high-resilience foam used in high-risk applications sold on the basis of protection from product liability.

"At this point," James says, "most of us are dead in the water."

More movement will be apparent in the market for high-performance chlorinated hydrocarbon flame retardants, which is dominated in the U.S. by Occidental Chemical. Use of Occidental's Dechlorane line of additives, says manager of performance chemicals Earl H. Levith, will grow at an average rate of 7 to 9% over the next five years. On the other hand, he concedes, the company's HET chlorendic acid, a reactive flame-retardant chemical, probably will grow at no better than a 2% annual rate for the next two to three years, rising to the pace of GNP after that. HET probably accounts for somewhat more than half of Occidental's flame-retardant chemical sales in poundage.

Almost all HET produced goes into unsaturated polyester resins, a sector that has been severely battered by the recession because of its reliance on transportation and marine recreation applications. According to Society of the Plastics Industry statistics, U.S. consumption of flame-retardant polyester resins plunged 26.5% over the first 11 months of 1982 compared to the same period the year before.

That is why Occidental is aggressively focusing its attentions on Dechlorane. The major markets for Dechlorane are cross-linked polyethylene and ethylene-propylene rubbers for wire and cable applications, polypropylene, nylon 6 and 6/6, and some epoxies and adhesives. Overseas, Dechlorane is used in polybutylene terephthalate, a market Occidental would like to break into in the U.S.

But Occidental will encounter brominated flame-retardant chemicals in a number of applications treated with halogens.

"Dechlorane is pretty mature," remarks Levith, "so we are going after new segments of the market. We're spending a lot of money on R&D for Dechlorane. We're very aggressive as far as working with customers goes, finding new products for them."

Polyvinyl chloride, urethanes dominate flame-retardant chemical use in plastics

Millions of lb of flame retardants[a]	ABS	Epoxy	Unsaturated polyester	Poly-olefins	Poly-styrene	PVC	Poly-urethanes	Others	Total
Antimony oxide	2.6	1.3	1.3	3.3	4.3	15.9	—	4.3	33.0
Brominated hydrocarbons	9.5	18.5	b	b	18.5	—	b	—	50.0
Chlorinated hydrocarbons	—	—	7.0[c]	b	—	21.0[d]	—	b,e	34.0
Boron compounds	—	—	b	—	—	b	—	b	7.0
Phosphorus-containing compounds									
Halogenated	—	—	b	—	b	—	18.0	b	23.0
Nonhalogenated	—	—	b	—	—	24.5	—	b	32.6
SUBTOTAL	**12.1**	**19.8**	**>8.3**	**>3.3**	**>22.8**	**>61.4**	**>18.0**	**>4.3**	**179.0[f]**
Alumina trihydrate	—	11.0	68.4	b	—	b	—	54.0[g]	180.0
GRAND TOTAL	**12.1**	**30.8**	**>76.7**	**>3.3**	**>22.8**	**>61.4**	**>18.0**	**>58.3**	**359.6[f]**

a Estimates for 1981. b Small application; data not available. c Mostly chlorendic acid. d Mostly chlorinated paraffins. e Mostly Occidental Chemical's Dechlorane. f Excludes polyols, molybdenum, zinc, and metal oxides. g For latexes used in carpet backing.

Reformulation in the quest for new flame-retardant products is the reigning dynamic in the antimony oxide industry as well. Sales of antimony oxide, which is used as a synergist with other flame-retardant chemicals except in inherently flame-retardant PVC, fell more than 20% last year. Although the recovery this year may bring a substantial rebound, growth over the long run is not expected to be any better than that of GNP.

"We're looking at existing halogenated flame-retardant additives and trying them in combination with antimony oxide in many resins," explains F. Joseph Prior, manager of product marketing for PPG Industries, the largest U.S. producer of antimony oxide. "Our thrust is to try to reduce the amount of additive required."

The antimony oxide industry has its problems. There is overcapacity in the U.S., but, despite the forecasts of a few years ago, no producer has gotten out of the business. Even more debilitating are imports, which enter the U.S. in great quantity and at low prices, forcing down the prices of domestic producers. Although companies admit this has helped them win some business away from competing materials on the basis of cost, it has hardly increased profits.

And producers also imply that opportunities in flame-retardant chemicals, even with reformulations, may be limited. "The flame-retardant area is maturing," Prior says. "There have been no new flame-retardant molecules in the past few years."

Antimony oxide makers have shifted at least part of their energies as a result to smoke suppression, an aspect of fire protection that many flame-retardant chemical producers believe is most likely to be addressed by regulators first.

"Our attention now is on smoke suppressants rather than on flame retardants," notes Ted Halchak, marketing manager for flame retardants and urethane catalysts at M&T Chemicals. "This is important especially in PVC and related applications."

Halchak says that M&T has been working on both synergist and additive smoke suppressants for a year now. At PPG, research has been under way for more than a year on smoke suppressants made from both antimony oxide and other materials. According to PPG's Prior, the company has found chemicals that reduce smoke generation 50%.

Work on smoke suppressants, in fact, is widespread in the flame-retardants industry. Occidental, for instance, reports Levith, expects regulations on smoke control, and has launched what he calls an "aggressive" program to develop products. "We're going to be in the forefront in smoke technology."

But other flame-retardant chemical makers warn that cashing in on the growing smoke-control market will not be easy. "We've looked at the commercial materials, and we haven't found a smoke suppressant that really works," says Great Lakes' Ludwig. "The problem is that when you load materials up heavily enough to try to reduce the smoke, you have a significant decay in properties that are important to the molded part."

Other flame-retardant segments are making similar attempts to reformulate their products to find new markets or strengthen their hold on old ones. Alumina trihydrate, for instance, which is the biggest volume flame retardant (it is, however, far less expensive than most other flame-retardant chemicals), finds the bulk of its flame-retardant uses in unsaturated polyester resins for molded bathroom fixtures and rubber latexes for carpet backing. Growth in these sectors is essentially that of GNP.

Solem Industries, however, produces a line of surface-treated alumina trihydrate, processed with a variety of silanes, stearates, titanates, and other agents. These new formulations give alumina trihydrate uses it did not have before in urethane foam, wire and cable coatings, carpet tile, and polyolefin injection-molded parts and sheets. Although surface-coated grades now account for a small share of the alumina trihydrate market, they ultimately could boost growth tremendously.

Solem's R&D coup is an achievement that other producers would love to match. In particular, companies would like to come up with more polymeric flame-retardant systems, because they do not have the performance and toxicity disadvantages of the additive chemicals. But because of fear that beneficial regulations will not appear soon enough, reluctance to assume the premarketing notification expenses entailed by the Toxic Substances Control Act (TSCA), or, in some cases, pessimism over the chances of expanding existing markets, many companies are carrying out research on limited budgets.

Technician at Witco Chemical's Pearsall chemical division exposes polyolefin fabric sample treated with new flame retardant to flame from gas torch in screening test

"Since TSCA, it's become very difficult and expensive to offer new products to the market," says Great Lakes' Ludwig, whose company is one of the more active introducers of new flame-retardant chemicals. "Therefore, you spend time in really improving what you've got or become a master of blendology. You tend to mix or combine materials to get certain advantages of each. You need to make sure the ball goes way over the fence, that it's a clear home run before you pump the dollars into developing it."

"TSCA is not a major problem," remarks Saytech's Innes. "It becomes a cost, but it does not hamper the movement toward new products. If the market is there, it will support the cost of the toxicity work." □

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here's where it stands Page 28

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MALIGNANT CELLS

Understanding how their genes go awry Page 8

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Cover: Mouse cell after taking up an oncogene. Micrograph courtesy of Mark Furth, Memorial Sloan-Kettering Cancer Center, New York

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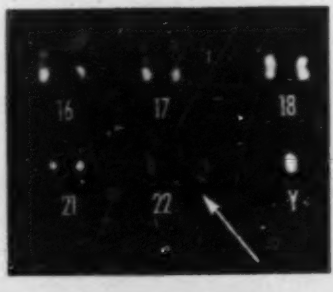

News Focus

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Chemical Stock Prices Rebound

Chemical stock prices have jumped by nearly half since last summer's low point; despite current low profits, Wall Street is bullish

William J. Storck, C&EN New York

On Wall Street, the current mood seems to be, ignore reality. In fact, pay no attention to earnings. Forget that most forecasters still predict slow recovery for the economy. And don't worry about huge federal budget deficits.

Instead, the stock market continues its startling, record-shattering climb begun last August. For those who view the market as a tried and true leading indicator of the economy, its rapid rise indicates that, poor forecasts to the contrary, the economy is going to be much healthier fairly soon.

For the past few months, the prospect of recovery in the economy, fueled now by falling petroleum prices, has sent the stock market to new heights. The Dow Jones Industrials Average, the most watched stock index, finished the week ending March 4 at yet another high of 1140.96, up 41.3% from a year ago and up 9.2% from the end of 1982.

A number of other factors indicate to Wall Street that better times are ahead. These include falling interest rates, which already have helped housing and automobile industries as well as the capital equipment markets; improvements in both business and consumer confidence; a sharp rise in the government's index of leading economic indicators; and relatively glowing accounts of the current state of the business pickup from private groups such as the National Association of Purchasing Management (C&EN, March 7, page 14).

In other words, the situation is almost the reverse of a year and a half ago, when high interest rates, worries over goverment policies in the money supply, and a general air of pessimism combined to drive stock prices down. For almost a year, the Dow Jones Industrials Average hovered in a range from the high 700s to the high 800s.

From that low point, the stock market idled for a few months and then last summer burst into the upswing that has now taken it to a new historic high.

In spite of the strong performance by the stock market, there is no unanimity on Wall Street about the short-term future of the market. Investors and analysts are divided into two main camps. First, there are those who think that this is a classic bull market and will continue to climb, come what may.

However, there is a strong body of feeling in the financial community that says that the market has been outdoing itself and that there will be a correction soon. This correction, it says, could lower the stock indexes by as much as 10%.

This camp says that the market has ignored what will turn out to be lackluster earnings performance by U.S. companies in at least the first quarter of this year. When earnings reports for the first three months begin to appear, it says, the market may well fall as investors realize that profits typically lag in an economic upturn. That's especially true in chemicals.

However, at present the market is still climbing and chemical stocks have taken full part in the current runup. C&EN's Chemical Stock Index hit bottom in June 1982, about two months before the stock market took off. (C&EN's index is a weighted index based on the stock prices of seven leading chemical companies: Allied Corp., American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Monsanto, and Union Carbide.) Since then chemical stocks have paralleled the general stock market, with a strong upturn after the beginning of the year.

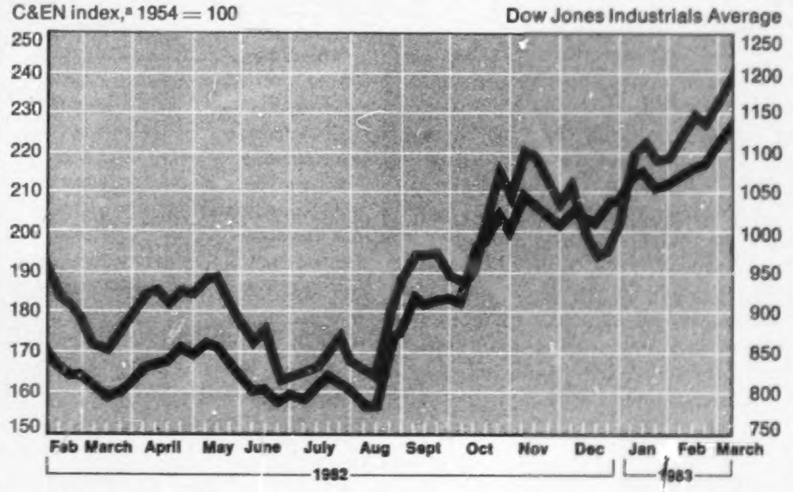
All stock measures are up more than 40% from year ago . . .

	March 4, 1983	March 5, 1982	12-month low	Change from year ago	Change from low
Dow Jones Industrials Average	1140.96	807.36	784.34	41.3%	45.5%
New York Stock Exchange Composite	88.63	63.14	59.69	40.4	48.5
New York Stock Exchange Industrials	101.88	70.43	66.82	44.7	52.5
American Stock Exchange Index	384.82	250.69	237.54	53.5	62.0
Over-the-Counter Composite	265.94	173.97	159.14	52.9	67.1
Over-the-Counter Industrials	319.33	194.76	177.70	64.0	79.7
Standard & Poor's 500	153.67	109.34	103.71	40.5	48.2
Standard & Poor's 400 Industrials	172.23	120.83	115.62	42.5	49.0
C&EN Chemical Stock Index	242	172	163	40.7	48.5

. . . and chemical stocks are near 12-month high

	March	12 month		% change
Stock price	4	Low	High	from low
Allied Corp.	$41¼	$28¾	$42⅛	43.5%
American Cyanamid	40½	24⅜	40⅝	66.2
Celanese	55⅜	41¼	59⅞	34.2
Dow Chemical	31¾	19⅝	32¼	61.8
W. R. Grace	42⅝	28½	43⅜	49.6
Monsanto	90	56⅝	90	58.9
Union Carbide	61⅝	40⅛	62⅛	53.6

Both Dow Jones and chemical indexes have gained more than 45% from lows



[a] C&EN index based on stock prices for Allied Corp., American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Monsanto, and Union Carbide.

C&EN's Chemical Stock Index has moved up more than 48% to 242 (1954 = 100) as of March 4 from a 12-month low of 163 as of June 18, 1982. Over the past 12 months, the C&EN index has risen 40.7%, just behind the Dow Jones Industrials rise of 41.3%.

In the week ending March 4, 654 stocks on the New York Stock Exchange reached new 12-month highs as opposed to only 14 with new lows. Again, the chemical industry was not left out. Of the seven companies on C&EN's index, five established 12-month highs—Allied, Cyanamid, Dow, Monsanto, and Carbide.

Besides the companies on the C&EN index, a number of other chemical firms set new 12-month highs that week: Air Products, Crompton & Knowles, Ethyl Corp., FMC, B. F. Goodrich, Hercules, International Minerals & Chemical, Loctite, Olin, PPG Industries, Rohm & Haas, and Witco Chemical.

The best performer on C&EN's index in the past year has been American Cyanamid. Cyanamid's stock price has climbed 56.5% to $40.50 from $25.875 a year ago. The rise has been fully 66.2% from Cyanamid's 12-month low of $24.375.

Not far behind, Dow Chemical's stock price has moved up 52.1% to $31.75 from $20.875 a year ago. And if investors had put money into Dow at its low of $19.50, they would have by now a 61.8% paper gain.

In the past 12 months, Monsanto has risen a very respectable 45.2% to $90 from $62 a year ago. And the stock price is up 68.9% from its 12-month low of $56.625.

Carbide's stock price in the past year has gone up 41.3% to $61.625 from $43.625. And from its summer low of $40.125, Carbide stock has risen 53.6%.

W. R. Grace has had a 12-month stock rise of 21.4% to $42.625 from $35.125 at this time last year. Its price is now 49.6% above its 12-month low of $28.50.

Allied, which has turned itself into an even more diversified company, has had only a 20.0% increase in stock price to $41.25 from $34.375 at this time in 1982, but it has risen 43.5% from its 12-month low of $28.75.

The lowest performer of the companies on C&EN's index has been Celanese, which showed a big earnings loss in fourth-quarter 1982 resulting in a loss for the year. However, Wall Street has some confidence in Celanese. At $55.375, the Celanese stock price is 5.7% above its year-ago level of $53.375 and 34.2% above its 12-month low of $41.25.

Even with these jumps, chemical stocks and the Dow Jones Industrials trail some of the other well-known stock market indexes. For instance, smaller stocks on other exchanges have performed even better in the current bull market. The Over-the-Counter Industrial Composite has vaulted almost 80% to 319.33 as of March 4 from its low last summer of 177.70. It also has increased 64.0% from its year-ago level of 194.76. The combined Over-the-Counter Composite has risen 67.1% to 265.95 from its low of 159.14 and 52.9% from its year-ago level of 173.97.

The American Exchange Market Value Index has gone up 62.0% to 384.82 from its 12-month low of 237.54 and 53.5% from 250.69 a year ago.

The broader indicators of large company stocks also have done better than have either C&EN's Chemical Stock Index or the Dow Jones Industrials' in recovering from their 12-month lows, but not all are up as much from a year ago. The New York Stock Exchange Industrial Composite increased 52.5% to 101.88 from its low of 66.82 and 44.7% from its year-ago level of 70.43. The combined New York Stock Exchange Composite has gone up 48.5% to 88.63 from its 12-month low of 59.69 but only 40.4% from its year-ago level of 63.14.

The Standard & Poor's 400 Industrial indicator has risen 49.0% to 172.23 from its low of 115.62 and 42.5% from a year ago.

Finally, the overall Standard & Poor's 500 indicator has increased 48.2% to 153.67 from its 12-month low of 103.71 and 40.5% from 109.34 a year ago.

Even with a possible breather on the way, the stock market looks vastly better than a year ago. There are now numerous predictions that the Dow Jones Industrials will top 1200 later this year. Such exuberance on Wall Street, if investors still have their traditional foresight, augers a much better economy this year and next than many business people would believe.

Again, this is the reverse of the opinion polarity a year ago during the economic slide. At that time, many on Wall Street and the stock market itself were predicting renewed recession, whereas most business leaders and government officials were confident of a 1982 recovery. No one would mind now if Wall Street were right. □

Texas' pre-eminence in chemicals is slipping

Probably few people would be surprised to learn that Michigan has lost its place on the list of the top 10 states in the U.S. for chemical manufacturing. After all, not only has Michigan long been ascribed one of the most inhospitable business climates in the nation, everyone knows that heavy industry in general is fleeing the northeast and midwest.

But it might batter a few assumptions to learn that Texas, with its long pre-eminence as a chemical center and friendly business climate, now ranks barely ahead of New Jersey in chemical shipments. Even more surprising would be the revelation that nowhere is chemical activity growing faster than in California, which is popularly considered one of the least advantageous places to do business. Statistics that show these and other trends between 1977 and 1980 have been gleaned from unpublished U.S. Census Bureau data by Inform, a nonprofit research group in New York City.

The most dramatic change from 1977 to 1980 was the weakened status of the Gulf Coast states, despite the general perception of an industrial boom in the Sun Belt. Compared to an industry average growth of 29.4%, chemical activity (measured on the basis of value of shipments minus the costs of materials and energy) increased only 10.7% in Texas and 22.6% in Louisiana. As a result, Texas' chemical activity was only 3.9% higher than New Jersey's in 1980. Louisiana, which ranked fourth in 1977, fell back to sixth in 1980.

In 1977, Texas and Louisiana together accounted for 18.7% of U.S. chemical shipments on a value-added basis. In 1980, on the other hand, the two states made up only 16.5% of that total.

The state with the largest percentage gain was California, where chemical shipments rose 47.8%. In so doing, California moved from seventh to fifth place at a time when its image was seemingly inhospitable to heavy industry. During the same three-year period, Ohio increased its chemical activity 42.2% and rose from fifth to fourth place.

The remaining top 10 states increased chemical activity at rates within a few percentage points of the industry's U.S. average. Most stayed where they were in the 1977 ranking, with the notable exception of Indiana, which moved from 11th to 10th place by nudging out Michigan.

Inform notes that the new figures contradict the popular notion that chemical producers are fleeing states with stringent environmental rules. California, which had the sharpest chemical growth, also has the nation's strictest hazardous waste and air pollution control programs. □

Texas still heads list of top 10 chemical-producing states

Rank	1980 $ millions[a]	1977 $ millions[a]	% change[b]	% of industry total	Rank in 1977
1 **Texas**	$ 8,090	$ 7,310	10.7%	11.0%	1
2 **New Jersey**	7,788	6,189	25.8	10.6	2
3 **Illinois**	4,566	3,507	30.2	6.2	3
4 **Ohio**	4,562	3,209	42.2	6.2	5
5 **California**	4,145	2,803	47.8	5.6	7
6 **Louisiana**	4,017	3,278	22.6	5.5	4
7 **New York**	3,956	3,121	26.7	5.4	6
8 **Pennsylvania**	3,470	2,761	25.7	4.7	8
9 **Tennessee**	2,988	2,276	31.3	4.1	9
10 **Indiana**	2,456	1,854[c]	32.5	3.4	11
TOTAL	$40,038	$36,308	26.8%	62.7%	
U.S. CHEMICAL INDUSTRY TOTAL	$73,382	$56,721	29.4%	100.0%	

a Totals represent value added by chemical manufacturers (the value of industry shipments minus costs of materials and energy). b Based on value-added totals. c Michigan ranked number 10 in 1977 with a value-added total of $1,876,100. **Source:** Inform

New proxy battle embroils GAF

GAF sometimes seems to have its share of hard luck. Not long ago, it went through an entire restructuring, selling off huge portions of unprofitable businesses, only to find itself in a recession that hit its building products operations hard, causing massive losses for the company.

And now, with the recession probably ending and the housing business expected to pick up, the New York City-based maker of building products and chemicals finds itself once more embroiled in a proxy fight.

The latest battle comes from Samuel J. Heyman, who operates a Connecticut real estate business and is a GAF stockholder. Last year Heyman began a proxy fight against the management of GAF, but dropped it when the company's chairman and chief executive officer, Jesse Werner, said that he was negotiating with another company for the acquisition of GAF. Werner also said at the time that there was interest by other companies in acquiring GAF's building products business.

The contest again this year is coming down to a fight between Heyman and Werner. Heyman says that he told Werner that he would drop the proxy fight if Werner would resign and says that he has offered to debate Werner. Heyman tells C&EN that for GAF last year to have advocated the sale of the building products business was "absolutely ill-advised."

Instead, Heyman would like to sell GAF's profitable chemical business to raise cash to pay off the company's long-term debt. However, this would leave GAF as a highly cyclical building products company where the main product has sustained operating losses for the past two years.

In a letter to stockholders, GAF says that Heyman has adversely affected discussions for the sale of the company. It says that two major companies will not enter a stock transaction because they do not want Heyman as a stockholder. The letter also states that GAF will "vigorously oppose" Heyman's attempt to take control of the company. □

Biomass Becoming More Important in U.S. Energy Mix

Projects aimed at developing biomass as an energy source are making good progress in tree culture, gasification, digestion, and liquefaction

Joseph Haggin, C&EN Chicago, and
James H. Krieger, C&EN Washington

The worldwide oil glut may have taken the edge off the thrust toward use of alternative sources of energy. Nevertheless, some energy sources are continuing to grow, particularly the use of biomass.

The amount of energy contributed by biomass and wastes to U.S. energy consumption has now increased to about 2.7 quadrillion Btu (quads), 3.5% of total consumption. It is projected to grow to about 3.5 quads by 1985.

Attention was drawn to that growth early this month, when the Bio-Energy Council released two publications connected with a seminar it conducted in Aspen, Colo., last summer for the Aspen Institute for Humanistic Studies. One publication—"The Increasing Use of Biomass for Energy and Chemicals"—presents the seminar highlights (and is available for $15 from the Bio-Energy Council, 1625 Eye St., N.W., Washington, D.C. 20006). The other publication—"Land Use, Food, Energy and Recreation," by Norman E. Borlaug—is of a public lecture at the seminar (and is available for $6.00).

Speaking at a briefing held to announce the publications and boost the visibility of bio-energy, Philip H. Abelson, editor of *Science* and vice chairman of the board of trustees of the Bio-Energy Council, emphasized the growth in use of biomass. "At a time when oil consumption has been decreasing in the U.S.," he noted, "bio-energy continues to grow at the rate of 50% every five years and today contributes almost as much energy as nuclear or hydro power does."

The Bio-Energy Council is a publicly supported, nonprofit organization created to stimulate industry, government, community, and scientific interests in development of bio-energy.

The council's briefing expands on a more detailed overview presented a month earlier by Donald L. Klass, vice president of the Institute of Gas Technology's education division. He spoke at the Seventh Annual Symposium on Energy from Biomass and Wastes, sponsored by IGT and held at Lake Buena Vista, Fla.

Together, the events underscore the growing importance in the U.S. energy mix of what is a very broad-based energy source. Indeed, the Bio-Energy Council, from an international point of view, tracks progress on nearly 2000 bio-energy activities in more than 60 countries.

Bio-energy encompasses activities ranging from the simple combustion of wood to the gasification of agricultural residues to the recovery of the methane/carbon dioxide biogas from municipal refuse landfills. It involves the development of techniques for improving production of biomass. And it involves the production of fermentation ethanol for blending with gasoline.

Federal support of R&D to develop energy from biomass and wastes continued to decline in 1982. But, Klass notes, much research and commercialization work has continued, and other funding sources are taking up some of the slack.

Gas Research Institute, for example, plans to invest about $75 million from 1982 to 1987 in R&D projects on methane from biomass and wastes. California's State Agricultural & Forestry Residue Utilization Act of 1979 has provided $10 million in state funds and stimulated an additional $36 million in industry commitments for development of bio-

Biomass' contribution to U.S. energy use is growing

Consumption, quadrillion Btu[a]	1975	1980	1981	1985
Petroleum[b]	32.731	34.301	32.122	30.313
Natural gas	19.948	20.495	20.215	17.795
Coal	12.823	15.626	16.109	18.526
Hydro	3.164	2.913	2.721	2.636
Nuclear	1.900	2.704	2.908	4.000
Biomass and wastes	1.750	2.583	2.661	3.467
Geothermal	0.081	0.121	0.138	0.210
Wind	0.082	0.003	0.004	0.012
Solar	0.001	0.011	0.015	0.051
TOTAL	**72.400**	**78.757**	**76.893**	**77.010**
% Fossil	90.5%	89.4%	89.0%	86.5%
% Nuclear	2.6%	3.4%	3.8%	5.2%
% Renewable	6.9%	7.1%	7.2%	8.3%
% Biomass	**2.4%**	**3.3%**	**3.5%**	**4.5%**

a Excludes cogeneration and waste heat recovery, purchased electric and steam, and net electric imports. b Includes natural gas plant liquids and liquefied refinery gases. **Source:** Resource & Technology Management Corp.

Biomass energy contribution comes from different sources

U.S. consumption, quadrillion Btu	1975	1980	1981	1982	1983	1984	1985
Wood and wood wastes	1.552	2.299	2.355	2.487	2.618	2.755	2.917
Municipal and industrial solid wastes	0.130	0.187	0.198	0.236	0.288	0.344	0.403
Sewage	0.046	0.054	0.056	0.059	0.062	0.066	0.070
Agricultural wastes	0.023	0.030	0.033	0.035	0.039	0.042	0.046
Alcohol fuels	—	0.009	0.014	0.014	0.015	0.018	0.021
Landfill methane	0.001	0.004	0.005	0.006	0.007	0.008	0.010
TOTAL	**1.752**	**2.583**	**2.661**	**2.837**	**3.029**	**3.233**	**3.468**

Source: Resource & Technology Management Corp.

mass energy projects. These projects are expected to result in net benefits to investors of $300 million during the estimated 20-year life of the projects.

Besides the institutional and state support of U.S. biomass energy activities, investment by private industry also plays a role. Although it isn't known how much this support amounts to, Klass notes, most of the industry support apparently is being made by oil companies.

In the short term, Klass says, wood and wood wastes are projected to continue through 1985 as the major contributions of biomass to primary energy consumption in the U.S. Landfill methane and alcohol fuels are expected to about double in contribution from 1980 to 1985.

One reason for the predominance of wood and wood wastes is their use by the forest products industry for energy. At the Aspen seminar, Weyerhaeuser vice president for R&D John L. Kulp noted that the industry now derives at least 50% of its energy from biomass and in a decade will be obtaining as much as 90% from that source.

According to Klass, growth in energy derived from combustion of wood and wood wastes is expected to continue in industry because wood-fired boiler construction as a percentage of new plant starts has increased steadily since 1977. As recently as 1980, he says, about 50% of all new boiler construction starts, excluding utility boilers, were designed to be fueled primarily with wood.

One of the newest wood-fueled power plants is a 22.4-MW cogeneration plant at Dow Corning in Midland, Mich., that just went on line last November. The plant produces 1250-lb steam (950 °F). Associated with the plant is a nearby 5-acre site where a 30- to 45-day supply of wood fuel for the plant is maintained.

In the effort to develop woody biomass energy, short-rotation intensive culture continues to be one of the main research targets. A Department of Energy program in the U.S. has been under way for five years, establishing field plots and growing trees to the point of first harvest. Jack W. Ranney, field manager of the program, told the Aspen seminar that farming trees for energy has a long-range potential of supplying an amount of wood equivalent to more than twice the total amount of bioenergy being used in the U.S. today.

The DOE program has more than 360 plots involving 40 tree species under evaluation. According to Ranney, the best three-year fields of wood grown on fertile lands without fertilizer have reached 23 to 24 dry metric tons per hectare per year, and poorer, fertilized lands have produced as much as 29 dry metric tons per hectare per year.

Other than direct combustion, gasification, digestion, and liquefaction are the major means of converting biomass to energy and/or chemicals. Klass says that in the case of gasification, a variety of gasifiers, including fixed- and fluid-bed types are being developed. At least 40 suppliers are offering various kinds of gasifiers on the market, but only eight of them have actually sold units, he says. Most of the gasifiers in operation have consumption rates of 1 ton per hour or less.

The largest gasifier in commercial operation is most likely a 100-ton-per-day slagging pyrolysis plant at Disney World. It processes solid waste collected from the Magic Kingdom and nearby communities to produce low-Btu gas for heating water. Completed last October, the unit is still being debugged.

Besides its use as a low-Btu fuel gas, the synthesis gas generated by gasifying biomass can be converted to chemicals. The most likely product from biomass-derived synthesis gas is methanol. Of the processes now under development, Klass believes that the one developed at Battelle's Pacific Northwest Laboratory affords the lowest production costs. At least five types of methanol processes are available, with production costs ranging from 64 to 77 cents per gal. None, so far, are being used for commercial production.

Intense efforts continue to be lavished on gasification by anaerobic digestion to obtain basic knowledge of the microbiology and of new, innovative ways to perform methane fermentation. Klass thinks that one of the most interesting reports in the past year was the recovery of certain thermophilic anaerobes from deep-sea volcanic environments. The anaerobes appear to be capable of producing methane, carbon monoxide, and hydrogen in certain media at 100 °C and atmospheric pressure.

Many research projects are in progress to improve anaerobic digestion, Klass says. For example, there are investigations of genetic methods to develop better strains of methanogenic bacteria, of autohydrolysis to increase the biodegradability of biomass, of the stimulatory effects of selected nutrients on acetate-grown methanogens, and of combined enzymic-chemical treatment to increase the conversion rate of hemicelluloses. And several research approaches to improved digestion performance are ready for scaleup from the laboratory or are being evaluated at the process development unit or pilot plant levels. These, Klass says, include dry fermentation, use of immobilized anaerobes that significantly reduce digestion times, upflow fixed-film digesters for wastewaters, and two-phase digestion in which the acid and methane formation phases are physically separated.

According to Klass, the number of commercial anaerobic digestion plants in the U.S. increased significantly during the past year, particularly advanced technology systems for industrial wastes. For example, the construction of a novel hybrid anaerobic digestion-rotary kiln in California's Ventura County was announced. The facility will produce 5.4 MW of electricity and 4 million cu ft of gas per day. The kiln will produce steam for turbines, and the wet organic portion of the wastes will produce gas.

Liquefaction of biomass can be direct or indirect. Direct liquefaction includes the natural formation of useful chemicals in plants and seeds as well as production of products by fermentation and rapid pyrolysis. Indirect liquefaction implies the conversion of the biomass to synthesis gas or some other intermediate, which subsequently is converted to the desired products.

Natural liquefaction in plants does provide useful products, but the economics generally are unfavorable compared with petroleum-derived materials. Low oil and fluid yields are the main reasons. The most competitive natural oil with a potential for heating oil production probably is sunflower oil, and it costs about twice as much as conventional diesel fuel from petroleum. The natural oil available in greatest volume is soybean oil. But, Klass points out, the production costs preclude serious attention being given to it as a potential fuel source. The possibilities for direct liquefaction seem to be limited to high-value products that can justify high production costs and extensive purification steps.

Sixty-five fuel ethanol plants were operating in 1982

Plant size, gal per year	Number of operating plants	Total capacity, million gal per year
100,000 to 499,999	14	3.66[a]
500,000 to 999,999	19	13.19
1,000,000 to 2,499,999	14	22.30
2,500,000 to 4,999,999	9	29.98
5,000,000 to 9,999,999	3	21.00
10,000,000 to 49,999,999	1	40.00
50,000,000+	5	340.00
TOTAL	65	470.13

[a] Includes 2.11 million gal of fermentation capacity for 190- to 192-proof ethanol. Source: Donald L. Klass

Flash pyrolysis appears to be plagued by practical operating difficulties with the pilot plants. Selectivity is poor and the complex products are difficult to separate. Most of the work on flash pyrolysis of biomass is on the bench scale and few projects are still in progress.

For ethanol fuel, the past year was crucial and dramatic, Klass says. Annual sales of ethanol in the U.S. jumped to about 210 million gal from about 74 million gal in 1981. Fermentation capacity for fuel ethanol has been projected for early this year to reach about 526 million gal per year of anhydrous ethanol, with 65 plants of 500,000 gal per year or larger on line.

This capacity is well below the goal of 920 million gal per year by the end of 1982 that was set by DOE's Office of Alcohol Fuels, as specified by Title II of the Energy Security Act. But, as Klass notes, fuel ethanol use and capacity are increasing rapidly.

Several factors account for fuel ethanol's success. First, although the Reagan Administration had intended to eliminate the federal excise tax exemption of 4 cents per gal for gasohol and the federal investment tax credits of 20%, both are still in effect. And indeed, the exemption will increase to 5 cents per gal on April 1 as a result of the new federal gasoline tax and is intended to stay in effect until 1992. Both benefits are expected to give ethanol fuel a new boost.

Another factor is that marketing efforts are phasing out the term gasohol, which had achieved something of a stigma. As an octane enhancer, ethanol holds its own economically. Hence, the new marketing approach simply notes that a given gasoline contains ethanol—or, as one brand points out, it is "fortified" with ethanol.

A third factor in fuel ethanol's success has been the depressed price of corn. This situation, Klass says, has permitted more flexibility and higher profit margins for fuel ethanol producers in the open market. In fact, fermentation ethanol has been competitive with synthetic ethanol recently because of increased ethylene prices and low corn prices. Forecasts suggest that by 1990 fermentation ethanol will be 25 cents per gal cheaper than synthetic.

To keep matters in perspective, Klass points out that alcohol fuel's displacement of gasoline in U.S. markets is minuscule. In 1981, the amount of gasoline displaced by ethanol was about 0.07%. Existing methanol capacity is about an order of magnitude larger than that for ethanol, so its potential to displace gasoline is much greater than that for ethanol. Still, the potential market for alcohol fuels is extremely large.

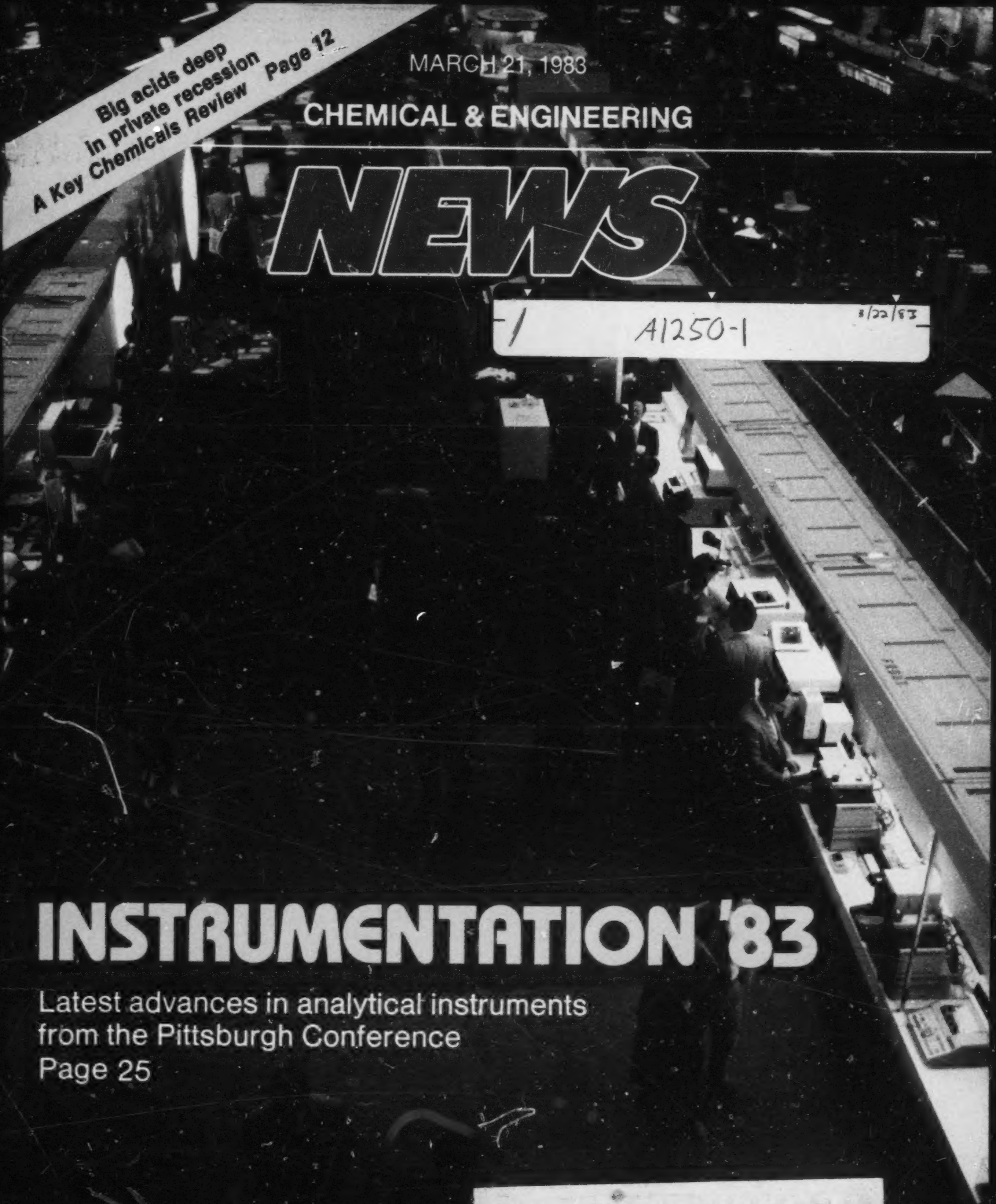
Methanol has been touted for some time as a logical successor to fermentation ethanol in the long run. However, its fuel use has been hampered by legal restrictions. The Environmental Protection Agency requires that gasoline contain no more than 0.3% by volume of methanol. In recent months, numerous waiver requests to increase the allowable methanol content have been made. Du Pont, for example, has asked to use methanol at concentrations of up to 3%. Late last month, however, EPA decided against the petition, citing the possibility of increased emissions from auto fuel systems as the reason. Indications are that Du Pont, and others, will revive the petition and resubmit it immediately in another attempt to increase allowable methanol content.

Past experience with methanol in fuels has been mixed. Most of the problem appears to emanate from the solvent action of the methanol, particularly in older autos, which have accumulations of resins and tars in the fuel system. Also, there occasionally is a problem with gasket materials. All of these problems may be solved without much difficulty. On the positive side, methanol fuels do appear to provide good fuel values and are considerably cheaper than gasoline.

If the resubmitted petitions to increase the methanol content of gasoline are successful, the prospects for methanol fuels could improve dramatically because of the better profit margins over ethanol. One of the imponderables is the future course of oil prices and, therefore, of gasoline. Most of the methanol is expected to come eventually via syngas derived from biomass and coal. □

MARCH 21, 1983

CHEMICAL & ENGINEERING NEWS



Big acids deep
in private recession
A Key Chemicals Review Page 12

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INSTRUMENTATION '83

Latest advances in analytical instruments
from the Pittsburgh Conference
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CHEMICAL & ENGINEERING
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Business

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Government

International trade issues facing Congress will affect chemical industry's trade balance; long-term solutions sought. **Page 16**

Science

Number of women earning Ph.D.s in science has doubled in past four years, but discrepancies in salary and tenure remain, says updated National Research Council report. **Page 21**

Education

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New instrumentation at this year's Pittsburgh Conference points up the increasing role the computer is playing in the analytical laboratory. Page 25

Big-Volume Acids' Recession Likely To Continue

Sulfuric and phosphoric acids have little hope of joining general economic recovery in 1983; farm acreage controls hurt giant fertilizer market

Bruce F. Greek, C&EN Houston, and
William F. Fallwell, C&EN Washington

After living a charmed life in the first two years of the U.S. chemical industry's travails since 1979, big acids producers have lumbered into a private recession that could stretch far into the general economic recovery now getting under way.

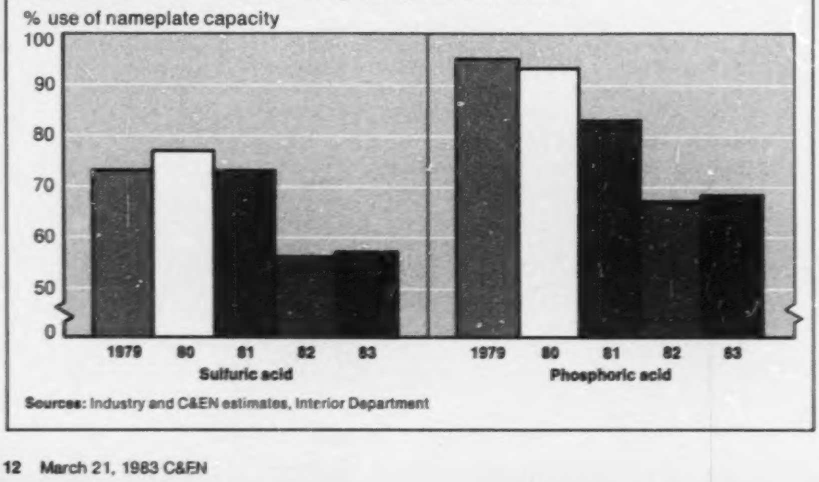
Everything has gone wrong for sulfuric and phosphoric acids, whose woeful immediate market prospects are detailed in the following pages. And that means a significant part of the chemical industry will remain financially depressed. Sulfuric acid ranks number one and phosphoric acid number nine in production volume among all U.S. basic chemicals. Nor are these two chemicals small potatoes in value, with a combined \$4.25 billion estimated for 1983.

This value figure, however, neatly sums up the acids' problems. It is fully 40% off the \$7 billion these giant inorganics were worth in the recent boom years around 1980. Obviously, prices have been smashed. And production has tumbled, a combined 27% from the 1980 peak, to the trough of 40.2 million tons (phosphoric acid measured as P_2O_5) in 1982. Even with a hopeful 3% production gain in 1983, volume will remain 24% below the recent peak. Average plant use will languish at 60% of total capacity.

Key Chemicals

Behind these doleful statistics is one main problem for both products: big trouble on farms around the world. The unremitting agricultural recession in the U.S. and abroad means a similar recession for phosphate fertilizer, which consumes 85% of U.S.-produced phosphoric acid and 70% of sulfuric acid. Even an unexpected turnaround for U.S. agriculture wouldn't save the acids completely, because nearly half of U.S. phosphoric acid winds up eventually in exports, and about two thirds of sulfuric acid goes into phosphoric acid.

Plant use will remain very low in both acids



Sources: Industry and C&EN estimates, Interior Department

The latest twist in the U.S. fertilizer market is the government's new acreage control effort called Payment-In-Kind, or PIK, whereby farmers are paid in cash and inventoried goods for the crops they don't grow. By attempting to shrink the product oversupply, PIK is hence both a price support and acreage reduction program. Its first test is the deadline just passed for farmers to sign up. Results are due shortly.

Theoretically, PIK could push fertilizer volume either way. Farmers might actually overfertilize remaining planted acreage to increase productivity, some analysts speculate. However, the more likely result is that, if unplanted acreage turns out to be a large percentage of the total, and farmers' financial plight is unrelieved, fertilizer use will continue to drop. Conservative forecasters predict a 10% cut in phosphate fertilizer use in the U.S. in 1983, largely because of PIK.

Then there's the export problem. It is exacerbated at the moment by the enormous debt loads in developing countries such as Brazil and India, which are some of the largest buyers of U.S. phosphoric acid and phosphates. For the future, U.S. products will face mounting competition from phosphates about to pour out of new production centers such as Morocco and other North African countries.

Put it all together and analysts fear that the big acids may have a long wait, possibly until the mid-1980s, for a return to high plant use and healthy profitability.

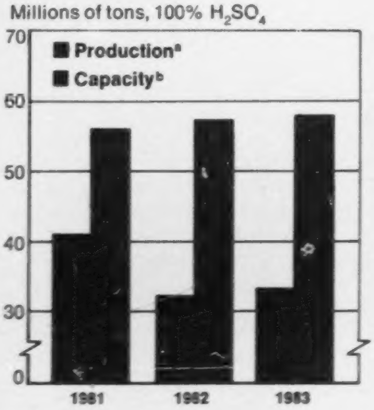
Key Chemicals

Sulfuric Acid

H_2SO_4

- ***Demand low***
- ***Capacity facing drop***
- ***Prices discounted***

PRODUCTION/CAPACITY



a From all sources. b First quarter.

HOW MADE

Sulfur dioxide from burning sulfur or from smelter gases oxidized and reacted with water

MAJOR END USES (U.S.)

Fertilizer 70%; chemical manufacture, metals processing, and petroleum refining, 5% each

FOREIGN TRADE

Exports—up to 250,000 tons in 1983; imports—possibly 500,000 tons in 1983, mainly from Canada

PRICES

List prices $55 to $80 per ton depending on location, with heavy discounting; smelter acid priced much lower

COMMERCIAL VALUE

$2 billion for production, 1983

The old, perhaps outdated, adage that as sulfuric acid goes, so goes the chemical industry, applied very well in 1982. A more than 20% decline in demand for this ubiquitous acid last year hinted correctly that all parts of the chemical industry had a bad time. More directly, the decline underscored the fact that the acid's dominant market, phosphate fertilizer, was a shambles.

Since prospects for the chemical industry are for improvement in 1983, the outlook for sulfuric acid is that output will be up modestly. Subject to many "ifs," acid production is expected to increase no more than 5% over 1982 production of about 32 million tons (as 100% H_2SO_4). It's likely, say industry analysts, that the increase will be about 3% to bring production to 33 million tons. So output still will be down sharply from 1981's 40.8 million tons and from the previous peak of 44.2 million tons in 1980.

A production decline of more than 25% in two years obviously has hurt sulfuric acid producers. Substantial plant capacity, up to 5%, has been shut down—an unusual event for the nonsmelter acid part of the industry. (Smelter acid usually fluctuates more in plant shutdowns and startups because this acid is a by-product of metals production.) Ordinarily, acid plants keep running even in times of low demand to minimize corrosion.

With substantial capacity down, notably in plants supplying acid for reaction with phosphate rock to make fertilizer-grade phosphoric acid, controversy has begun in earnest about real future acid capacity. Producers won't say that they have actually scrapped plants. Most likely, plants headed for the padlock over the next few years will slip away quietly, making capacity estimates undoubtedly too high.

Excluding smelter acid plants, sulfuric acid capacity now shut down is estimated at 1 million to more than 3 million tons per year. The higher figure is more than 5% of total first-quarter 1983 capacity of 57.5 million tons. Much of the remaining capacity, especially plants making acid for industrial uses, is running at low rates. Unfortunately, if smelter operations pick up as a result of higher copper demand, smelter acid will come to market at low prices and tend to hold down operating rates longer for plants making virgin acid.

If sulfuric acid production reaches 33 million tons in 1983, the plant operating rate will average less than 58% of first-quarter nameplate capacity. If, say, 2 million tons of capacity remains shut down all year, the operating rate for plants actually running still will not top 60%. Needless to say, business will be poor. That percentage figure for capacity use also makes it pretty clear that expansion money won't be around for some time.

Barring an unexpected surge in demand for phosphate and other fertilizers, sulfuric acid demand growth will stay 5% or lower per year, industry sources forecast. Therefore, production won't equal the 1980 level again until after 1985. A few capacity additions might come along, mostly captive plants, but much more old capacity will be gone by then. Operating rates will rise as a result, but hardly enough to help profitability.

Other than some improvement in the phosphoric acid market, prospects for greater sulfuric demand in 1983 are small. For instance, sulfuric's steel market may recover a bit, but the upturn is not expected to be large enough to help sulfuric acid output much. The situation is similar in other uses such as petroleum refining and chemical manufacture. A few of the small miscellaneous uses might be up significantly, as much as 10%, but their effect on sulfuric acid volume would hardly be noticeable.

Sulfuric's large overcapacity, especially in the Northeast, will keep downward pressure on prices. In turn, acid producers will keep pressure on raw material sulfur prices. Unfortunately, roughed-up sulfur pricing can work unfavorably for acid producers, whose customers will then expect savings to be passed on along. Hence, low raw materials' prices may not help acid producers' profit margins. In fact, further miserable pricing for sulfuric acid could hasten plant shutdowns and scrappage this year and next.

Overall, sulfuric acid faces scant letup in its own recession, even though the U.S. economy seems to be recovering. A pickup in industrial uses won't overcome sulfuric's market woes in fertilizer.

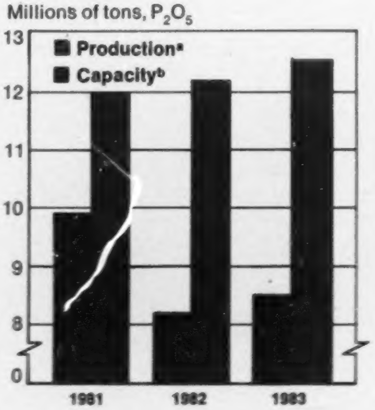
Key Chemicals

H_3PO_4

Phosphoric Acid

- ***Demand weak***
- ***Capacity gain ended***
- ***Prices slashed***

PRODUCTION/CAPACITY



[a] Both wet-process and furnace acid.
[b] First quarter.

HOW MADE

Reaction of phosphate rock with sulfuric acid; burning of elemental phosphorus and subsequent reaction with water

MAJOR DERIVATIVES (U.S.)

Ammonium phosphates 60%, triple superphosphate 20%

MAJOR END USES (U.S.)

Fertilizer 85%, detergents

FOREIGN TRADE (as acid)

Exports—falling below 1 million tons (as P_2O_5); imports—very small

PRICES

List prices $300 to $320 per ton for fertilizer; heavy discounting

COMMERCIAL VALUE

$2.25 billion for production, 1983

As the phosphoric acid world began to bristle with new investment during banner years in 1979 and 1980, some skeptical heads began to shake in consulting and banking circles. Unfortunately, the outsiders' cautionary advice was not heeded, and phosphoric acid today is deep in overcapacity woes as the market tumbles.

If that weren't enough, phosphoric acid producers have to tolerate some of the worst unknowns in all chemical marketing because of their dependence on farm markets—involving weather, strength of the dollar (affecting exports), farm commodity prices, and planted acreage. At the moment, these fickle influences are hurting phosphoric acid's major outlet in phosphate fertilizer, whose volume is well off this year. Minor, currently more stable, influences on the total phosphoric acid picture come from industrial, detergent, and food and beverage uses of specialized, generally purer acid made from elemental phosphorus.

The result of the unknowns in agricultural demand for phosphoric acid, plus a bit of optimism from industrial and other demand, is a slightly improved outlook, say analysts. For 1983, they put production of phosphoric acid at about 8.5 million tons (measured in terms of P_2O_5). That would be up less than 5% from a weak 8.2 million tons in 1982. Last year's output was off fully 17% from 1981's 9.9 million tons. So even a slight upturn in production in 1983—a controversial prediction at that—would leave phosphoric acid depressed.

A second straight poor production year is having severe effects on producers. At the moment, substantial capacity is shut down even though the big spring marketing season is starting. No capacity additions other than minor debottlenecking and other efficiency improvements have been announced for more than a year.

Although some plants are shut down, little if any capacity has been scrapped so far, indicating that phosphoric producers, like farmers, always can hope their luck will change. Some of the currently shut-down plants may never run again, but owners don't yet hold this view.

Plenty of incentive exists for plant scrappage. In 1983, the average plant operating rate may be a lowly 68%, barely up from 1982. These rates are roughly the same as in past depressed periods such as the mid-1960s.

Parallels to that time are very much on the minds of today's managers in the wet-process phosphoric acid industry. Severe overcapacity then caused a virtual halt to plant expansion for six to seven years. During that time, demand for phosphoric acid continued to grow and then caught up with capacity in the 1974–75 and 1979–80 boom years. In 1979 and 1980, production ran above nameplate capacity at times, as fertilizer producers strained to meet demand in U.S. and fast-rising export markets. Then began the round of large capacity additions just completed. The obvious current question is: Are phosphoric acid producers facing another several years of waiting for demand to catch up to their expensive new capacity?

Long-term recovery in phosphoric acid demand is expected to depend entirely on agricultural markets, with fertilizer accounting for most of the recovery. Industrial uses of phosphoric acid have slipped from about 1 million tons per year (as P_2O_5) in the early 1970s to about 700,000 tons and are expected to hold there for some time. Animal feed uses climbed to more than 500,000 tons per year but are expected to hold there or rise very slowly.

For 1983, some industry sources say that growth in phosphoric acid production for fertilizer may have to come strictly from traders and other risk takers buying in at depressed prices for future inventory profits. Actual farm use of phosphate fertilizer probably will be down, possibly as much as 10%.

However, fertilizer production still could grow for two types of inventory building. In the first case, dealer inventories apparently dropped substantially in 1982 as use of fertilizer exceeded production. So dealers now may partially rebuild inventories, aided by lower interest rates.

In the second case, fertilizer exports declined in 1982 and are expected to show little improvement even with the help of lower oil prices. However, lower oil prices and economic recovery could boost exports in 1984, and traders could build inventory this fall to meet such sales.

Women With Ph.D.s Gaining Rapidly in Sciences

Study shows supply of women with doctorates in science is up 50% in past four years; salary, tenure problems, however, are continuing

Four years ago, when the National Research Council took its first look at the status of doctoral women scientists in academic institutions, it concluded that the number of women in such positions was increasing slowly but that there were sex differences in salaries and in the awarding of tenure.

This month the council published an update of that study. Instead of the slow increases of four years ago, women with Ph.D.s are now gaining rapidly in numbers in both academic and industrial sciences. In the past four years the total supply of women with doctoral degrees in science or engineering has increased 50%. However, the discrepancies in salaries between men and women Ph.D.s, and in the likelihood of achieving tenure in academic positions or managerial jobs in industry will continue.

The new report, like its predecessor, was prepared by NRC's Committee on the Education and Employment of Women in Science and Engineering. The committee continues to be headed by Lilli S. Hornig, executive director of higher education resource services at Wellesley College, and M. Elizabeth Tidball, professor of physiology, George Washington University Medical Center.

A new report was called for, the committee says, for several reasons. Since the first report, which covered trends in employment through 1977, the number of women scientists and engineers completing graduate school has grown much faster than the number of positions available at colleges and universities. The committee wanted to know whether women were disproportionately affected by the relative scarcity of academic jobs.

Also, the committee wished to find out whether the modest gains of women in the mid-1970s seen in the first survey had been sustained and whether the salary differentials observed in the earlier study still continue. Finally, the present study amplifies the earlier one by including an examination of the status of doctoral women scientists and engineers in industry as well as at academic institutions.

"The most striking change that has taken place since 1977 is the growth in numbers of doctoral women scientists," the report says.

"Among new doctorates, men and women have very similar characteristics, including the age at which they complete the Ph.D., the type of Ph.D.-granting department, and what their plans are for the immediate future," the report finds. "Males and females in the same field are about equally likely to opt for a postdoctoral appointment, or if they plan to be employed, will go into

Salary differential between men and women chemists is one of the largest

Field	Median salary Women	Men	$ Difference	% Difference
Full professors				
Mathematics	$34,700	$36,700	$2000	5%
Physics	37,000	38,000	1000	3
Chemistry	**31,000**	**36,000**	**4400**	**12**
Medical science	35,900	42,100	6200	15
Other bioscience	34,100	36,700	2600	7
Psychology	34,500	37,700	3200	9
Economics	36,400	42,200	5800	14
Associate professors				
Mathematics	27,800	28,600	800	3
Physics	—	28,600	—	—
Chemistry	**27,000**	**28,700**	**1700**	**6**
Medical science	30,200	32,800	2600	8
Other bioscience	27,000	28,300	1300	5
Psychology	27,100	27,200	100	0
Economics	30,100	32,700	2600	8
Assistant professors				
Mathematics	22,400	22,600	200	1
Physics	22,500	23,300	800	3
Chemistry	**20,700**	**22,400**	**1700**	**8**
Medical science	25,100	28,000	2900	10
Other bioscience	22,000	23,200	1200	5
Psychology	22,400	21,600	800	(4)
Economics	—	24,100	—	—

Note: Salaries are for full-time employees at four-year colleges and universities in 1981. **Source:** National Research Council industry or academe at similar rates."

Once employed, however, differences between men and women scientists begin to appear. At academic institutions, doctoral women scientists are still more likely than men to be employed as instructors or lecturers, positions from which they cannot be promoted or achieve tenure. In most fields, this discrepancy has grown since 1977. In chemistry, for example, 5.3% of the women, compared with 2.7% of the men employed in academe in 1977, were in these nontenure-track positions. In 1981, 7.0% of the women and 2.1% of the men held such positions.

Even women who are eligible for tenure take longer to achieve it, on average, than their male colleagues. In the 50 institutions that have the largest R&D expenditures, for instance, three fourths of the men who were assistant professors in 1977 had been promoted to a higher rank by 1981. Only half of the women assistant professors at these same schools were promoted during that period, the study found.

However, there are signs that the increases in the number of women in junior faculty positions that took place between 1973 and 1977 are now being reflected at the associate professor rank. The sex differential in tenure at the associate professor level also has narrowed since 1977, and at the assistant professor level, a slightly higher percentage of women than men now have tenure.

Sex differences in faculty salaries persist in most fields, the study finds, with the largest differences occurring in chemistry and medical sciences. Women assistant professors in chemistry earn, on average, $1700 per year less than men do, the study finds.

In industrial employment as well, women scientists and engineers have made substantial numerical gains in the four years covered by the study. From 1977 to 1981 their numbers more than doubled, from 1700 to 3500, although they still account for only 5% of all Ph.D.-level personnel in industry.

Women are gaining better foothold in universities . . .

	Women scientists and engineers as % of total	
	1977	1981
Professor	2.5%	3.1%
Associate professor	6.6	9.8
Assistant professor	16.1	23.5

. . . but still less likely than men to be promoted

	% promoted from assistant professor rank in 1977 to higher rank in 1981	
	Men	Women
Top 50 institutions[a]	73%	47%
Other institutions	70	57

[a] The top 50 institutions by federal R&D expenditures in fiscal year 1980. **Source:** National Research Council

Only 16.4% of the women scientists in industry say that their primary work activity is management, compared to 28.7% of men. Women in industry are more likely than men to be employed in basic research (12% of women, compared with 8% of men), consulting (10% of women, compared with 7% of men), writing (2% of women, compared with 1% of men), or "other activities" (16% of women, compared with 9% of men).

As it did four years ago, the committee has several recommendations for improving the status of women scientists and engineers. It urges science departments to give further attention to the rates of promotion of men and women within the department. "Much of the focus of affirmative action efforts in the past has been at the entry level. The findings of this report suggest a need to take that one step further and examine the comparative advancement of those hired as assistant professors," the committee says. Attention also needs to be given to the increasing number of women who are in off-ladder positions in academe.

Copies of the report, "Climbing the Ladder II: An Update on the Status of Doctoral Women Scientists and Engineers," are for sale for $8.95 (prepaid) from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418. ◻

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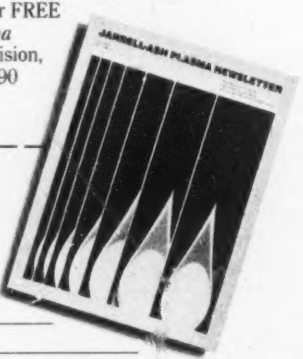

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CHEMICAL & ENGINEERING NEWS

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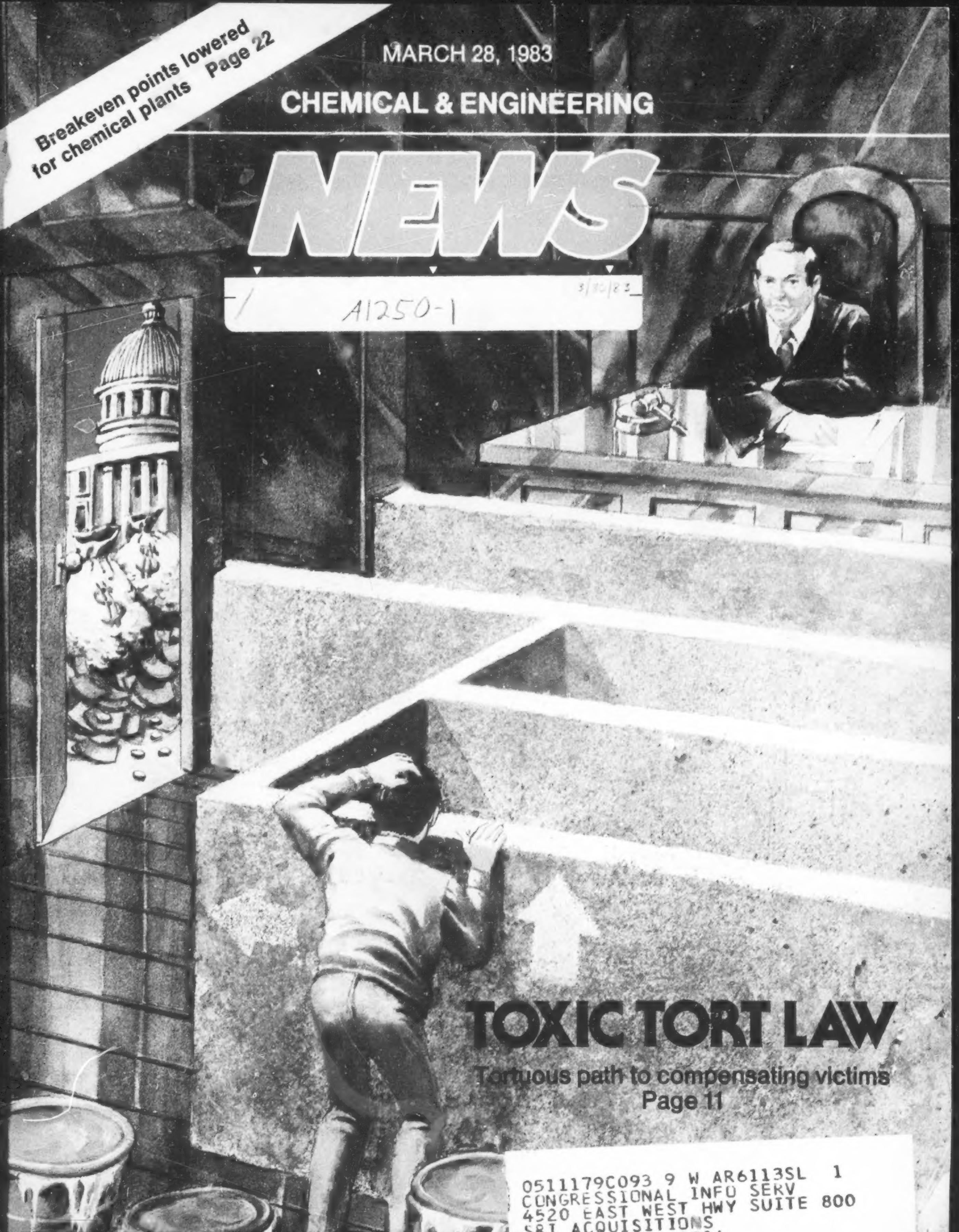
Breakeven points lowered for chemical plants Page 22



TOXIC TORT LAW

Tortuous path to compensating victims
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CHEMICAL & ENGINEERING NEWS

MARCH 28, 1983

News of the Week

- **Hydrogen binding to a transition metal complex observed directly for the first time.** **Page 4**
- **ACS Council in Seattle ups dues and subscription prices, decides on other matters.** **Page 5**
- **Potent inhibitor of cancer, sesbanimide, defined structurally in x-ray-based analysis.** **Page 6**
- **USDA's payment-in-kind program draws varied reactions.** **Page 6**
- **Photographs from Seattle capture some of the meeting's bustle and the city's beauty.** **Page 7**
- **Nomination of Ruckelshaus to head EPA invites speculation on environmental policies.** **Page 8**

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Business

Lower break-even points for chemical producers signal potential for generating higher profits this year. **Page 22**

U.S. chemical firms are spending more on R&D facilities than in past, according to study done at University of Wisconsin. **Page 24**

International

Science data bank is expanding, soon will provide ready access worldwide to information on several new areas. **Page 25**

Japan's chemical trade suffered $550 million deficit last year, indicating a step down in its competitive struggle. **Page 28**

Government

Opening months of 98th Congress are fruitful; social security jobs, appropriations/authorizations progress smoothly. **Page 30**

Science

Tricoordinate silicon ion synthesized successfully in solution by using alkylthio substituents to stabilize ion. **Page 33**

Priestley Medal Address

Robert S. Mulliken, 1983 recipient of ACS's highest award for his contributions in chemistry, reminisces on his career. **Page 36**

Books

"Early Life" by Lynn Margulis draws analogies between ecological problems today and those from life's beginnings. **Page 40**

News Focus

Victims of exposure to toxic substances get their day in court; legal remedies start to take shape. **Page 11**

claimed by the biggest firms. In some ways, it is much easier for the large commodity chemical producers to lower their break-even points. As Salomon Brothers' Ravitz says of the capital-intensive majors, "Those with the largest costs have the easiest row to hoe."

Many of these cost-cutting options are unavailable to specialty chemical producers. Not being nearly as capital-intensive, specialty companies cannot reap the same benefits from shutting down a plant that commodity firms can. Even more to the point, employment cutbacks are extremely dangerous for specialty makers because of the overriding importance of marketing and service in their businesses.

"Specialty companies find it hard to cut their break-even points significantly," says Charles J. Rose, specialty chemicals analyst at Oppenheimer & Co. "They can't afford to chop break-even points that much. The guts of their business is people."

Rose, who estimates that specialty producers probably have not been able to lower their break-even points by more than a few percentage points on average, points out as well that as the specialty chemical business becomes more competitive, which it is doing rapidly, cutting employee levels becomes even more problematic.

For those companies that have achieved a reduction of 10% or so in their break-even points, the question now is how long they will be able to keep it that way.

"It's not theirs to keep forever," warns First Boston's Raman. "It's a moving target. I don't think there's a good appreciation of that. Everybody's running around saying, 'Hey, the break-even points are down, and therefore as soon as demand comes up we're going to print money.' I don't agree with that at all."

Most analysts, however, think the lowered break-even points are good cause for optimism. "Will they be able to continue to maintain these break-even points?" says Hutton's Henry. "I think the answer is yes."

"It's real," declares Citibank's Todd. "When production turns up, there will be a direct effect on the bottom line." □

Chemical firms spending more on R&D labs

U.S. industry is spending a lot more on facilities for R&D than it has in the past, and the chemical industry is certainly taking a healthy part in this trend.

This is one of the findings in a study funded by Flad & Associates, a laboratory design and engineering firm in Madison, Wis.

The study, which was carried out by faculty and students of the University of Wisconsin, Madison, under the direction of Michael J. Houston, associate professor, school of business, with help from the National Science Foundation, shows that capital spending for industrial R&D laboratories in the U.S. is expected to increase 60% in 1982–84 period. Capital spending for laboratory equipment probably will increase about 31% over the same period. Flad surveyed 682 laboratory managers to learn these results.

According to the study, the chemical industry will take a big part. Almost all of the chemical companies surveyed reported that they planned to spend much more in 1982–84 than in the 1979–81 period.

For instance, paints and allied products, which show the largest increase among chemical-related industries, plan to increase laboratory capital spending to $4.96 million per company in 1982–84. This is 291% above average spending of $1.28 million for the previous three years.

The largest average spending per company and the second largest percentage increase show up in drugs and related products, where a boost of 166% will take spending to an average of $6.03 million per company in 1982–84 from the previous three years.

In both per cent increase and total expenditures per company, drugs are followed by industrial organic chemicals, where spending per company in 1982–84 will average $5.05 million, up 132% from the previous period.

Agricultural chemicals, which like drugs are heavily R&D oriented, will get a 129% increase to $3.62 million per company.

The only decrease in laboratory facilities spending is for industrial inorganic chemicals, where spending per company will fall 21% to $1.06 million from 1979–81. This category and one other also have the only drops in the planned laboratory equipment spending. Expenditures for equipment will fall 1% in 1982–84 to $2.25 million for industrial inorganic chemicals. And equipment spending for cleaners and toilet goods will fall 24% to $438,000 per company.

Paints and allied products companies plan the largest increase in equipment spending, just as they do in facilities spending. The average per company will increase 70% to $1.84 million. Next come drugs and related products, where per-company spending will rise 50% to $2.25 million.

Agricultural chemicals also will get a boost, with equipment spending rising 55% to $1.40 million. □

R&D plant spending will outpace that for equipment for the period 1982 through 1984

Average per company, $ thousands	Plant spending			Equipment spending		
	1982–84	1979–81	% change	1982–84	1979–81	% change
Industrial inorganic chemicals	$1063	$1350	−21%	$2248	$2274	−1%
Plastic materials & synthetics	4727	2329	103	3491	2545	37
Drugs & related products	6031	2267	166	2252	1408	60
Cleaners & toilet goods	3524	1901	85	438	574	−24
Paints & allied products	4960	1267	291	1841	1081	70
Industrial organic chemicals	5049	2177	132	4291	3285	31
Agricultural chemicals	3617	1581	129	1402	906	55
Miscellaneous chemical products	1771	1008	76	1685	1320	28

Source: Flad & Associates

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CHEMICAL & ENGINEERING NEWS

ALLELOCHEMICALS

Plants' own herbicides
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Cover: USDA's Gerald Leather cuts off a
native wild sunflower leaf from which
allelopathic compounds will be extracted.
Photo by Eric H. Poggenpohl

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CHEMICAL & ENGINEERING NEWS

APRIL 4, 1983

News of the Week

- **Scientific community's reactions vary on Reagan's hope for more definitive R&D for defense.** Page 5
- **Current business recovery doesn't change long-run problems despite temporary oil price drop.** Page 6
- **Superconducting magnet is the heart of new NMR instrument that produces good body images.** Page 6
- **Possible future shortages of science and engineering personnel won't affect chemists.** Page 6

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News Focus

Lead additives to Europe's gasoline may be on the way out; debate centers on possible adverse health effects. **Page 7**

Business

Virginia utility's spent nuclear fuel problem may be resolved by dry-cask storage and fuel-rod consolidation. **Page 15**

U.S. methanol and ammonia markets will change, as decontrol of natural gas will make their production cheaper overseas. **Page 16**

Government

Proposed research budget cuts at National Bureau of Standards prompts Congressional hearings. **Page 19**

Science

News from the Seattle meeting: norbornyl cation controversy; higher conductivities of polymer films; Chemistry and the Law's first symposium; photolytic cells; Kolthoff's award. **Page 21**

Newly inaugurated Center for the History of Chemistry has varied set of programs, including Priestley birthday celebration. **Page 26**

Technology

Mapping hydrocarbon gas seepage into surface soils made easier; some zeolite catalysts found to direct molecular flow. **Page 30**

Education

Sciences/humanities gap can be bridged by stressing more of the humanistic dimensions of science to science majors. **Page 31**

Special Report

Nature's own herbicides, allelopathic agents, are getting closer look by scientists for agriculture uses. Page 34

processing was banned. The government would operate interim storage facilities until a permanent disposal repository became available. Congress, however, provided neither legislation nor funding. The utilities were stuck with rapidly filling spent-fuel pools and no additional storage capacity in sight, he says.

Vepco started making its own moves several years ago. In 1978 and 1979, it installed new storage racks in both the Surry and North Anna spent-fuel pools, effectively doubling capacity at both sites. It also developed a plan to ship spent fuel from Surry to first the North Anna 1 and 2 pool, and then to a new pool that would be built as part of a planned third North Anna unit.

Unfortunately for Vepco, Louisa County, in which North Anna is located, passed an ordinance that prohibited storing spent fuel in the county that wasn't generated in the county. Vepco challenged the ordinance in court, and a few weeks ago the courts ruled that the ordinance was invalid. The county, however, is appealing the decision.

Meanwhile, the company canceled plans for a North Anna 3 unit and lost the storage space that it would have supplied. Also, Congress passed the Nuclear Waste Policy Act, under which the government takes clear responsibility for permanent storage of spent fuel.

The problem, Smith says, is that the government has until 1998 to accept spent fuel, and Vepco's storage space at Surry could run out next year. Meanwhile, Vepco interprets the act as saying that responsibility for interim storage rests with those who produce the spent fuel. Although the act does provide federal interim storage, it isn't clear exactly who is eligible and how soon that storage will be available.

Vepco needs help next year. As a result, says Smith, the company has revised its plans once again. The new plan is designed to meet Surry's immediate needs and the company's longer-term storage requirements for all four of its nuclear units.

First, to avoid potential shutdowns, Vepco plans to double storage capacity at North Anna's pool by installing new, neutron-absorbing storage racks. It can't do this at Surry because the pool there won't take the added weight. And even the license application for the new North Anna racks is being contested by Louisa County and a citizens group.

In addition, Vepco plans to ship up to 500 spent-fuel assemblies from Surry to North Anna for interim storage. These shipments must begin next spring at a rate of about 30 shipments per year. The legality of these shipments still is in the courts, but Vepco is confident that the decision allowing it to ship will be upheld.

With reracking at North Anna and shipping from Surry, Vepco can extend its full-core discharge capability at Surry until 1990 and at North Anna until 1992. After 1990, however, the company will need still more storage space. This is where the proposed dry-cask storage, which will be used at Surry, comes in. Dry storage is expected to see the company through 1998, when permanent disposal likely will be available.

To raise the odds that dry-cask storage can be licensed in time to meet its 1990 requirements, Vepco plans to participate in two federally sponsored demonstration projects designed to prove the feasibility of dry-cask storage. But just in case, Vepco is designing and preparing license applications for an additional water storage pool at Surry. It's an expensive alternative—about $100 million to $125 million, according to Smith. But the company feels that it has to cover its flanks.

It also intends to try another new technology to cut costs and provide still more storage capacity. The technique is spent-fuel-rod consolidation, in which fuel rods are removed from their assemblies and placed in stainless-steel cannisters. Because a single dry cask can hold twice as much consolidated fuel as it can nonconsolidated fuel, only half as many casks would be needed at Surry. And, because the pool at North Anna can accommodate consolidation with little or no modification, its capacity could be nearly doubled.

With its long-term program of dry-cask storage and consolidation, Vepco will have enough spent-fuel storage capacity to meet its needs until the year 2005, Smith says. That's seven years after the government is scheduled to begin accepting delivery of commercial spent fuel for permanent disposal.

The technology, he says, is available for the most part. And the regulatory climate is favorable. However, he says, spent-fuel disposal is still a "highly emotional and politically volatile" issue. Although Vepco's latest plan sounds good, anything can happen to require still another revision.

Earl Anderson, New York

Gas prices to alter methanol, ammonia uses

Methanol and ammonia are chemicals at a crossroads. Traditional methanol uses are stagnant, and solid growth over the rest of the decade hangs on fuel-related applications that barely exist today.

Ammonia's fertilizer applications—which account for four fifths of consumption—will not even manage an average 2% per year growth between now and 1990. And because many nations will have cheaper natural gas than the U.S. after decontrol, methanol and ammonia, which together account for 9% of all natural gas used for industrial purposes in the U.S., will cost more when produced in the U.S. than when made overseas with inexpensive feedstocks.

These are some of the conclusions reached in a new study on the outlook for natural gas use in methanol and ammonia production in the U.S. conducted by Chem Systems, a Houston research firm.

According to Chem Systems, methanol imported from Canada, Mexico, the Middle East, and the Pacific Basin nations will make up an increasingly larger portion of the U.S. market, competing with U.S. product for the few segments that show growth. The methanol industry, which was still a net exporter in 1982, will be importing 18% of demand by 1985, and 19% by 1990. Ammonia, already a net importer, will develop along the same lines. Imports, which made up 8% of demand in the 1981/82 season, will account for 11% in 1984/85 and 17% in 1989/90.

In making these and other forecasts, Chem Systems assumes that the overall long-term growth rate of the U.S. gross national product will average 3.2% in real terms; that U.S. and world crude oil prices will show no increase in 1983 and rise at only 2% per year in real terms after that; that there will be no natural gas price "fly up" in 1985 (on the assumption that indefinite escalator clauses in natural gas contracts will be legislatively constrained); and that the average free-market price of gas will come to equal that of low-sulfur residual fuel oil for major industrial and utility users with alternate fuel capability.

Since Chem Systems sees methanol's major traditional uses, formaldehyde, acetic acid, and others, as essentially mature, it expects real growth to come from the application of methanol as a motor fuel. Although there are major technical and infrastructure problems in the way, methanol's gasoline-related uses—whether as a straight fuel, in fuel blends, or in additives like MTBE (methyl *tert*-butyl ether)—are expected to grow at a 16.1% rate between 1981 and 1990. That would raise the gasoline-related sector's share of end uses from 17% to 28%.

By 1985, however, feedstock natural gas will represent more than 85% of the cash cost of producing methanol. On that basis, the report notes, the greater the difference between U.S. and overseas natural gas prices, the more vulnerable U.S. methanol producers will be to imports.

Ammonia producers are even more tied to natural gas than methanol makers. Whereas about 87% of U.S. methanol uses gas as a feedstock, 97% of ammonia is gas based. Rising gas costs combined with depressed ammonia demand and low-priced ammonia imports (some landed in the U.S. at prices below the feedstock cost alone for U.S. producers tied to expensive gas contracts) already have forced the permanent or temporary shutdown of about 20% of U.S. ammonia capacity over the past five years, and more plant closings are expected during the 1983/84 season. Chem Systems expects some plants to restart when demand picks up in 1984/85, but imports will supply most of the future growth in U.S. demand.

If it were not for the import threat, the report notes, the likelihood of rising gas prices in the U.S. pushing up ammonia prices would not be a serious marketing problem, since there is no good substitute for nitrogenous fertilizers. Because natural gas for feedstock and fuel will account for more than 83% of the production cost of ammonia by 1985, however, makers of cheaper ammonia overseas are expected to view the U.S. as an increasingly attractive market.

The greater presence of imports and marginal developments in energy efficiency actually will reduce the amount of natural gas consumed in ammonia production over the decade, Chem Systems predicts. As technical improvements bring gas consumption per metric ton of product down nearly 5 million Btu between 1981/82 and 1989/90, overall gas use in ammonia production will drop from 519 billion cu ft to 494 billion cu ft.

To a lesser extent, the same process is anticipated in the methanol industry. Gas consumption per gallon of methanol will be cut about 18,000 Btu over the same period. That will keep down overall gas use growth, seen as rising from 133 billion cu ft in 1981 to 159 billion cu ft in 1990. □

Fuel uses will dominate the methanol market . . .

Millions of gal unless otherwise specified	1981	1982[a]	1985[b]	1990[b]	Average annual change 1981–90
DEMAND					
Formaldehyde	430	360	500	560	3.0%
Acetic acid	140	140	190	270	7.6
Power generation	4	—	10	100	39.5
Gasoline-related	157	180	450	602	16.1
Others (DMT, solvents, methylamines, methyl methacrylate, methyl halides, etc.)	439	370	550	652	4.5
TOTAL	**1170**	**1050**	**1700**	**2184**	**7.2%**
SUPPLY[c]					
Production	1270	1200	1400	1760	
Net exports (imports)	100	150	(300)	(424)	
Natural gas consumption (average)					
Millions of Btu/gal	0.1234	0.1139	0.1073	0.1053	
Billions of cu ft	133.1	116.1	124.7	158.5	

a Estimate. b Forecast. Source: Chem Systems

. . . but fertilizer uses for ammonia will grow very slowly

Thousands of metric tons as N unless otherwise specified	1981/82	1984/85[a]	1989/90[a]	Average annual change 1981/82–89/90
DEMAND				
Fertilizer	11,652	12,476	13,761	1.9%
Fiber, resin, elastomer intermediates	884	1,060	1,341	4.7
Explosives	438	444	460	1.0
Livestock feed	90	120	145	5.4
Miscellaneous	1,109	1,350	1,510	3.5
TOTAL	**14,173**	**15,446**	**17,237**	**2.2%**
SUPPLY[b]				
Production	12,855	13,746	14,237	
Net exports (imports)	(1,094)	(1,700)	(3,000)	
Natural gas consumption (average)				
Millions of Btu/gal	41.252	38.364	36.446	
Billions of cu ft	519	501	494	

a Forecast. Source: Chem Systems

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Chemical industry fights maturity
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CHEMICAL & ENGINEERING NEWS

Syngas to ethylene glycol

Catalyst solves low-pressure route Page 41

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CHEMICAL & ENGINEERING NEWS

APRIL 11, 1983

News of the Week

- **Du Pont will seek court review of unfavorable FTC ruling in price signaling case.** Page 6
- **Opposition to increased defense spending gains support from chemical executives.** Page 7
- **Acid spill in Denver controlled with soda ash.** Page 7
- **On-line service now available for 18 ACS research journals.** Page 7
- **GAF introduces first polymer coating to clean rust and scale from metal surfaces.** Page 8
- **More study needed on payment to victims of toxic waste, says chemical makers group.** Page 8

Business

A maturing chemical industry still shows promise for short-term growth, but long-term prospects will need a boost. **Page 11**

International

Canada's chemical producers, beginning to see signs of recovery, still must cope with the feedstock pricing problem. **Page 16**

Government

U.S. position on acid rain control is blamed for setbacks in U.S.-Canadian containment of environmental pollution. **Page 20**

House Budget Committee views R&D in favorable light; funding levels frozen or increased for science agencies. **Page 23**

Science

News from Seattle meeting: selective laser excitation; ultrahigh resolution chromatography; nuclear fragmentation reaction; liquids and solutions; ultraviolet use in pest control; and more. **Page 25**

Technology

ACS meeting news: upgrading of heavy hydrocarbons; wood pulping by-products; activation of methane bonds; and other stories. **Page 43**

Books

"The War Against the Atom" by Samuel McCracken presents a flawed case as defense for nuclear energy. **Page 49**

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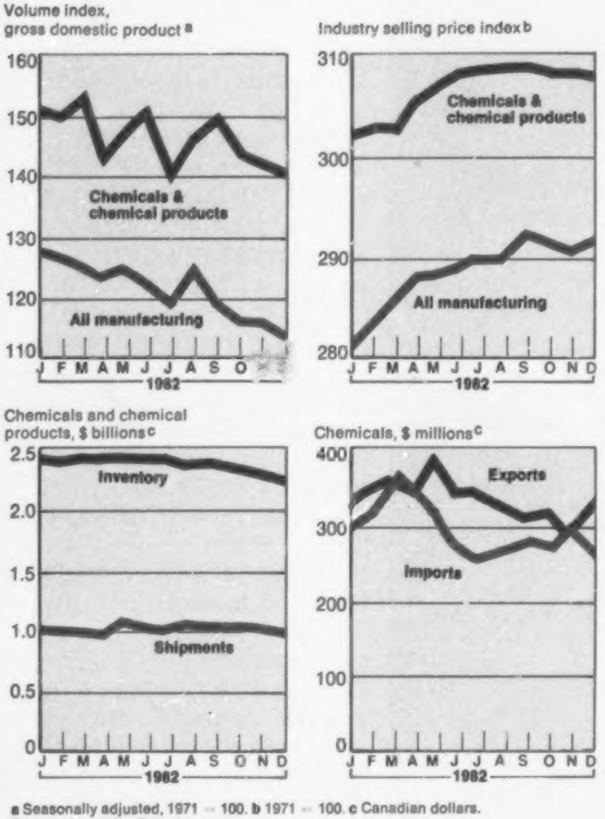
Cover Story

Two new catalytic routes to ethylene glycol start from synthesis gas and formaldehyde. Page 41

Canadian Chemicals See Recovery



a Seasonally adjusted, 1971 = 100. b 1971 = 100. c Canadian dollars.
Source: Statistics Canada

Canadian chemical output: hoping for better

Production, thousands of metric tons	1982	1981	1980	% change 1981–82
ORGANICS				
Ethylene	1013	1330	1196	−23.8%
Propylene	618	671	594	−7.9
Benzene	504	572	560	−11.9
Toluene	470	480	470	−2.1
Xylene	396	409	403	−3.2
PLASTICS				
Polyethylene, low density	376	410	439	−8.3
Polyethylene, high density	195	223	202	−12.6
Polyvinyl chloride	194	222	190	−12.6
INORGANICS				
Nitric acid	977	1158	712	−15.6
Phosphoric acid[a]	503	744	808	−32.4
Sulfuric acid	3131	4117	4295	−24.0
Ammonia, anhydrous	2509	2654	2555	−5.5
Ammonium phosphate	888	1355	1466	−34.5
Chlorine	1233	1292	1303	−4.6
Sodium hydroxide	1367	1458	1459	−6.2

a 100% P_2O_5. **Source:** Statistics Canada

Signs of economic recovery are sprouting in Canada. This has to be good news for Canada's beleaguered chemical industry, which crawled out of 1982 dripping in red ink.

The big questions now on the minds of most Canadian chemical executives are how strong a recovery will the economy stage and, even if it is as strong as many forecasters predict, will that be enough to put the industry back solidly into the black?

Unfortunately, the Canadian chemical industry, particularly the petrochemical segment, still has to contend with its exasperating feedstock pricing problem. Because of the government's inflexible energy pricing policies, Canadian feedstock costs were rising last year at the same time that they were falling almost everywhere else.

For an industry that depends heavily on exports and upon a competitive edge in feedstock costs to sustain those exports, that is an intolerable situation. And last month's $5.00 drop in OPEC benchmark prices only complicates the Canadian petrochemical feedstock pricing situation even more.

The ball is in the politicians' court—those in Ottawa and those in Alberta. The 1981 agreement between the federal government and Alberta that established energy pricing policies came only after long and often bitter negotiations. Scrapping that agreement and devising a replacement will be equally tough, but that's what might have to be done. However it's done, there's a general consensus in Canada that energy prices have to come down.

While the chemical industry keeps one eye on energy pricing developments, it will keep its other eye on the economy. And what happens to the Canadian economy depends in no small measure on what happens to the U.S. economy. About two thirds of all Canadian exports end up in the U.S. For chemicals, the figure was 63% last year.

Early in the forecasting season, economists were saying that real growth in Canada's gross national product would be about 1 to 2%. Now some are daring to go as high as a 4% gain, compared to a 4.8% drop last year. One big reason: The better-than-expected performance of the U.S. economy in the first quarter is pulling Canadian economic fortunes upward with it.

If the U.S. economy remains buoyant and if it manages to act as a locomotive for other countries, it could have a significant bearing on Canadian chemical operations. That's because the more widespread the economic upturn, the better the prospects for Canadian chemical exports will be.

Canadian chemical exports fell 12% last year to just over $4 billion (Canadian). Nothing would help the industry more than to get those exports higher this year.

Earl Anderson, New York

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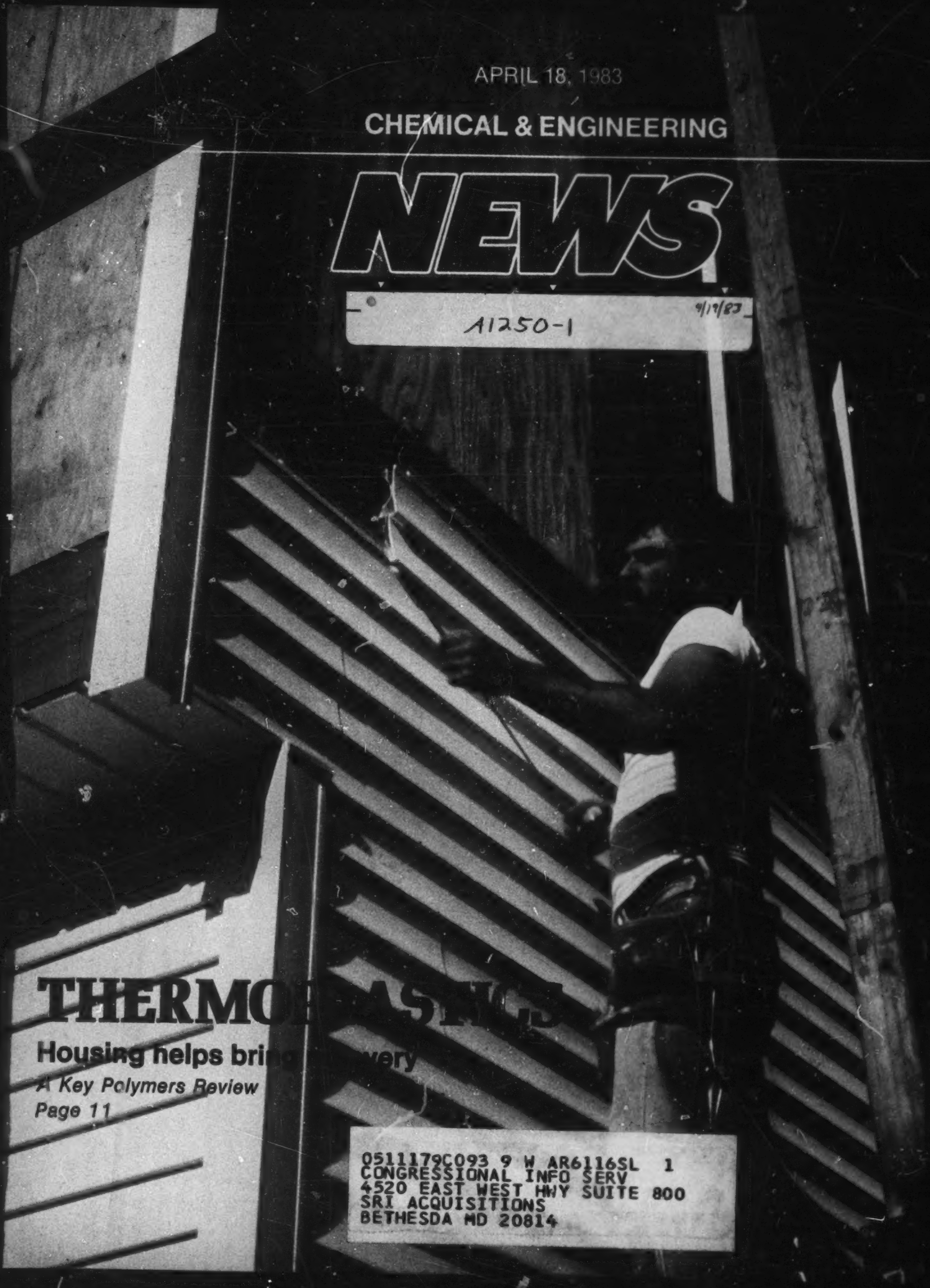

THERMOPLASTICS

Housing helps bring recovery

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Cover: Workman installs polyvinyl chloride siding on new house. Photo courtesy of B. F. Goodrich Chemical

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CHEMICAL & ENGINEERING
NEWS

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News of the Week

- **Synthetic fibers show signs of wider recovery as housing upturn boosts nylon use.** Page 6
- **Edward Knapp, nominee for head of NSF, makes it through Senate confirmation hearings.** Page 7
- **GAF has a busy week as it finds two buyers for its building materials group.** Page 7
- **New method to regenerate whole plants from protoplasts could accelerate biotechnology.** Page 8
- **Federal court overturns ban on urea-formaldehyde foam use in home insulation.** Page 8

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Business

Chemical firms' information services lead other industrial groups in number of libraries and international library systems. **Page 18**

Government

Industry survey on federal cost control recommends changes at the management level and some trimming of R&D budgets. **Page 23**

Administration's 1984 proposed budget favors chemistry research at academic institutions, according to AAAS analysis. **Page 24**

Science

Novel synthesis of kopsane alkaloids' complex cage structure opens access to family of biologically potent alkaloids. **Page 34**

Synthesis and isolation of 1,5- and 1,7-azuloquinones serve to test theories; entrapping metal catalysts in synthetic vesicles enhances performance and ensures stability. **Page 35**

ACS Annual Report

Society enrolled record 12,021 new members in 1982; Chemical Abstracts Service celebrated 75th anniversary. **Page 37**

Technology

Organic calcium chemistry separates phenol and derivatives from heavy coal hydrocarbons using calcium hydroxide. **Page 58**

Science Policy

Agriculture's road to the future looks rocky, but experts express hope; new techniques may lessen global food problems. **Page 59**

Cover Story

Uses for thermoplastics, such as in the housing industry, have begun to recover, but so far production outruns demand. **Page 11**

Output of Thermoplastics Turns Up In Modest Recovery

Housing is promising market and others may contribute, but plastics' production gain still may be limited to 6% and plant capacity use to 72%

Bruce F. Greek, C&EN Houston

Relief is sweet. Recovery finally has begun for major U.S. thermoplastics after three years pockmarked by recession. Few in the industry dispute this. But there are big questions about the strength of the upturn for the five leading resins detailed on the following pages—conventional and linear low-density polyethylene, high-density polyethylene, polypropylene, polyvinyl chloride, and polystyrene.

During the fourth quarter of 1982, production and sales of these thermoplastics began heading up after a bad tumble in the second and third quarters. This upturn has continued in the first half of 1983 but is not necessarily gathering strength. The added production to some extent is meeting a real increase in demand, but it also is fattening inventories in anticipation of added sales later this year and in 1984. In other words, production is outrunning real demand at the moment.

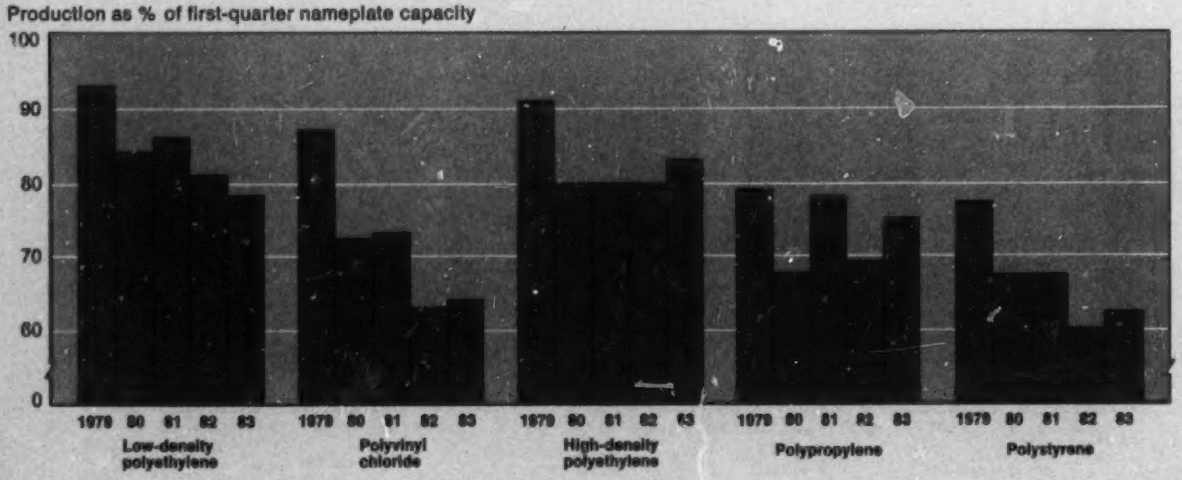
Among major markets, housing has picked up strongly from its depths of 1982. However, as far as thermoplastics are concerned, the pickup in this market really has just begun. There is an order lag between the start of a house and sale of the plastic products that go into it—siding, pipe, carpet, furniture, appliances, and other items. So recovery strength for plastics in housing likely will build by 1984. By that time, other parts of the plastics-heavy consumer durables economy may again get moving—for example automobiles, which are nosing up very slowly so far.

Key Polymers

Disappointment that the current recovery in thermoplastics is not as vigorous as in past recoveries may be inevitable. Slower recovery is the rule now simply because of the maturing of the industry. Double-digit annual growth rates for big-volume thermoplastics are considered a thing of the past. Growth rates of less than 5% per year are the standard forecast now for the 1980s.

For early 1983, recovery on a weight basis (as opposed to dollar basis) appears to be running at about a 6% annual rate. If this pace keeps up, production of the five major thermoplastics could total 25.9 billion lb this year, up 1.5 billion lb from 1982, although still down 3% from 1979's record 26.7 billion lb. The increase could be a third higher if optimists' views prove out that

Capacity use for leading thermoplastics will stay low in 1983



Sources: Industry and C&EN estimates; Society of the Plastics Industry's Committee on Resin Statistics certain plastics, notably low-density polyethylene and polyvinyl chloride, push 100 million or 200 million lb over forecasts. In that case, 1983 combined production could rise 2 billion lb or 8% over 1982 levels.

The money side of the thermoplastics business, very depressed in 1982, is also looking up. The combination of greater volume and, to a lesser extent, higher prices expected later in 1983 probably will push up the value of 1983 production for the five plastics at least $1 billion, or 14%, from 1982 to a combined $8.3 billion. This is still 13% less than the record $9.5 billion in 1981.

This shortfall says something about plastics' price problems. Average selling prices for the five plastics fell to 30 cents a lb in 1982 from the high of 37 cents in 1981. Prices may inch up to 32 cents a lb in 1983. That would give an increase of about 8% for the year. Even with this increase, plastics won't be very profitable. Significant further increases will be needed this year and later, most industry analysts agree, to generate future investment funds.

Oddly, plant capacity for three of these five thermoplastics—low-density and high-density polyethylene and PVC—still grew in 1982. At the beginning of 1983, capacity for all five totaled 35.7 billion lb a year, up 4% from a year earlier and up 16% from 1979. Since production has gone the other way, capacity use has sagged from 86% in 1979 to 71% in 1982 and about 72% in 1983.

Prospects for capacity growth in 1983 are dimmer. Additions will be coming for low-density and high-density polyethylene and polystyrene but nothing else. Little further capacity expansion seems likely until 1985 or later, except in linear low-density.

In fact, total capacity could sink a bit over the next year as permanent shutdowns outpace additions. Currently, C&EN includes in capacity estimates a lot of plants "temporarily" shut down. Some of these are really down for good and eventually will be deleted from capacity totals.

Some capacity additions still could take place but more subtly through technical advances. Polypropylene is a good example. For some time, catalyst improvements have increased capacity without reactor additions and with very minor additions of other equipment.

Offsetting some of this capacity increase will be a productivity loss incurred in the growing number of polymer grades now offered. Productivity suffers as producers take time to shift process conditions to make these various grades.

Another dent in capacity use arises from plastics' growing dependence on U.S. markets as exports fade because of new plants with low-cost feedstocks starting up in other parts of the world. The decline may begin this year, and exports are expected to be down for all major thermoplastics except polystyrene.

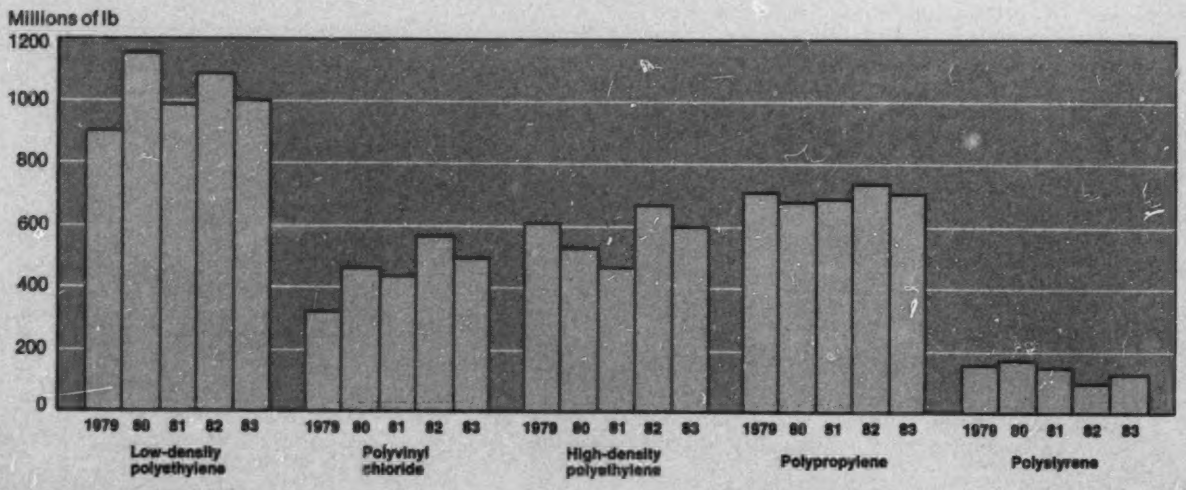
An export drop will hurt. Except for polystyrene, exports of major thermoplastics take 10% or more of production, a significant slice. As the export decline sets in, producers hope to innovate more in U.S. markets to make it up. But producers will be faced later in the 1980s with a rising tide of imports, either as polymers or as fabricated products.

Analysts say this new intensity of competition will bring basic changes in thermoplastics. For example, polymer producers are expected to move further into fabricated products such as the trademark polyethylene bags now on the market. As this move develops, some producers, especially smaller ones, will become more specialized in polymer production.

Such specialization moves also could intensify inter-polymer competition. Past examples include polypropylene varieties taking markets from polystyrene, or high-density polyethylene moving into other plastics' pipe markets.

Although plastics producers may recast their business into specialties eventually, they have a lot of slow-moving commodities to deal with this year. And commodities have to follow the slowly rising trend in the overall economy. It's a time of recovery but also of patience.

Thermoplastics' previously strong export market will erode in 1983



Sources: Industry and C&EN estimates; Society of the Plastics Industry's Committee on Resin Statistics

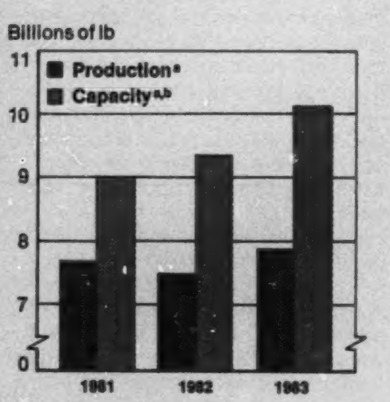
Key Polymers

$\left[CH_2-CH_2 \right]_n$

Low-density polyethylene

- ***Demand rebounding***
- ***Capacity growing***
- ***Prices still low***

PRODUCTION/CAPACITY



a Includes linear low-density polyethylene. b First quarter; includes some shut-down capacity not expected to restart.

HOW MADE

Polymerization of ethylene at high and low pressures aided by catalysts and initiators

MAJOR FABRICATED FORMS (U.S.)

Film, largely for packaging, 65%; coatings 10%; injection molding 5%

FOREIGN TRADE

Exports—large, but may drop to less than 1 billion lb in 1983, imports—less than 40 million lb

PRICES

List prices 28 cents per lb and up; discounts varied and sizable

COMMERCIAL VALUE

$2.5 billion for production, 1983

Low-density polyethylene weathered the recession a little better than expected and will make a run for record U.S. production this year. Producers have enough confidence that capacity expansions continue, mostly in the new, linear low-product type. Still, plant use rates and profitability aren't very good, and the resin's important export market is due for a drop.

Production of low-density polyethylene declined just 3% in 1982 from 1981 to 7.5 billion lb. For 1983, production could bounce back to a new high of 7.9 billion lb, possibly more if linear low-density polyethylene demand reaches optimists' expectations. The record is 7.8 billion lb in 1979.

Both production and sales of this polymer ran above the expected 1983 rate of gain in the latter part of 1982. This unsustainable pace apparently was due to inventory building as interest rates declined and buyers all through the sales chain, from polymer producers to end-product distributors, believed they saw a business pickup. However, analysts say this growth rate, more than 12% for December 1982 over December 1981, can't be maintained for 1983 as a whole.

Plant capacity for low-density polyethylene continued to grow in 1982. This growth equals the net of plant additions for conventional and linear low-density polyethylene minus permanent shutdowns in conventional plants. The largest addition in 1982 was Exxon Chemical's plant at Mont Belvieu, Tex., with capacity of 600 million lb per year of linear low-density polyethylene.

Other additions and subtractions brought total nameplate capacity to 10.1 billion lb as 1983 began, up 9% from a year earlier. Of additions due in 1983, the vast majority will be accounted for by Eastman Chemicals and Mobil Chemical, which are building the last of the conventional low-density plants in the U.S. In addition, process technology improvements will add some linear low-density capacity, and there will be some shifting of older high-density units to make this form of polyethylene.

Not all of this capacity actually is producing. At least 500 million lb currently is shut down and not expected to operate again, at least at the present locations. Probably another 500 million lb, possibly more, of capacity is temporarily shut down. All shut-down capacity uses the older, high-pressure technology, whose economics have been eclipsed dramatically by the new, low-pressure processes.

Subject to market demand, some temporarily shut-down capacity might be converted to make linear low-density material. However, costs of conversion compared to costs of new plants or costs of conversion of high-density polyethylene plants make forecasts almost impossible on the outcome of the current capacity excess.

The likely result in 1983, unless an unusual demand surge comes along, is that more than 1 billion lb of capacity will remain idle. If production reaches 7.9 billion lb, remaining capacity will run at a very decent 87%. Counting all shut-down capacity, the plant-use rate for the year will drop to 78% from 81% in 1982. The recent high in plant use was 93% in 1979.

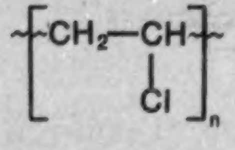
On the market side, U.S. uses of low-density polyethylene, counting all resin forms, will have roughly the same pattern as in recent years, with film dominating. Growth in film use will account for most of the production gain, excluding inventory building. This will favor linear low-density material, which goes largely into film. Further help here for linears will come from quality improvements.

Outside the U.S., low-density polyethylene faces a different picture. As with many other U.S. chemicals, exports will suffer because of the high value of the dollar and competition from new foreign plants with lower-cost feedstocks. After reaching almost 1.1 billion lb in 1982, close to the all-time high in 1980, exports of low-density polyethylene are forecast to drop 10% to about 1 billion lb in 1983.

The export sag will combine with competition for U.S. sales to take a toll on profitability and lead to more plant shutdowns. Efforts to raise polyethylene prices seem continuous but with little result. Enough new capacity will become available in 1983 that the pricing/profitability situation will remain much like 1982 despite a respectable volume increase. So this plastic will have a smart upturn in many respects but without much financial reward.

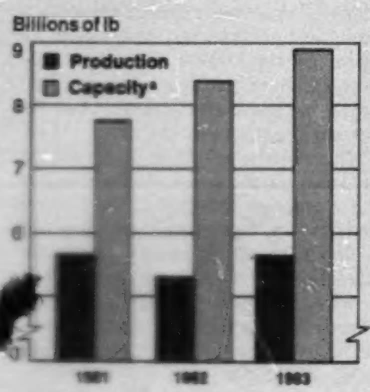
Key Polymers

Polyvinyl chloride


$\left[CH_2-\underset{Cl}{\underset{|}{CH}} \right]_n$

- ***Demand recovering***
- ***Capacity shaking out***
- ***Prices turning up***

PRODUCTION/CAPACITY



a First quarter

HOW MADE

Polymerization of vinyl chloride by suspension, emulsion, bulk, or solution processes initiated by free radicals

MAJOR FABRICATED FORMS (U.S.)

Extrusions, nearly two thirds pipe 65%; calendered sheet, film 10%

FOREIGN TRADE

Exports—declining to about 500 million lb in 1983, imports—staying about 50 million lb

PRICES

List prices unsettled, starting at 28 cents per lb; discounting large

COMMERCIAL VALUE

$1.5 billion for production, 1983

Signs of recovery finally are coming through for polyvinyl chloride, but it will take some time for this plastic to recover from the tumultuous times of the early 1980s. In 1983, even with a moderate production rebound powered by an improved construction market, polyvinyl chloride plants will bump along at only 64% of nameplate capacity.

The result will be a continued shakeout in this business, with more plants closing and more producers heading for the exit. In this respect, PVC is starting the new business cycle far different than in the late 1970s, when plant use strained the limit at 87% of capacity in 1979 and expansions rolled on and on.

PVC gets these wild cyclical changes in part because it is the thermoplastic most tied to the gyrating construction market, which takes a bit more than half of total U.S. PVC output. If home furnishings and other consumer items used around the house were included, construction's share of PVC demand would be still greater.

Unfortunately, at the beginning of a business recovery as at present, PVC lags construction because of the multistage pipeline extending back from construction sites to plastic extruders to resin producers. This "line-fill" time can account for as much as half a year, depending on perceptions of demand strength at different stages of the pipeline.

Currently, these perceptions indicate strong coming PVC demand in construction. Spurred by lower interest costs, these assessments call for renewed inventory building and increased PVC production, continuing a trend begun in late 1982. For 1983, output now is heading back to the 1981 level of 5.7 billion lb, possibly higher by 100 million to 200 million lb. This increase of 8% or higher still would leave PVC shy of its 1979 record of 6.1 billion lb.

As 1983 began, operable PVC plant capacity totaled 8.9 billion lb per year, but probably 1 billion lb of this was not running. How much shut-down capacity eventually will restart is difficult to estimate; not much will be tempted out under current financial conditions.

Later this year, startup decisions obviously will depend on PVC prices, including the differential between polymer and monomer prices. At this time efforts are under way to raise PVC prices. Part of the reason is that monomer prices are being pushed up under pressure from price hikes in raw material chlorine. With such cost pressure from the rear and with a moderate demand increase in front, PVC producers seem likely to get some price hike during 1983.

If, however, resulting price increases of a few cents per lb are not enough to cause shut-down PVC production units to restart, actual operating capacity of 8 billion lb will run at 71%. If production reaches 5.9 billion lb, the operating rate could rise to 74%. But, if all available capacity were included in the computation, operating rates would range from 64 to 66%.

At these levels of operation, PVC profitability is iffy. Price increases could help, along with greater volume, but the question remains: Is there enough money in PVC to justify development work to broaden uses of this versatile thermoplastic? Small producers probably cannot finance projects such as developing new compounds aimed at light and weather resistance—for example, in construction uses of siding and windows. These producers also can be at a cost disadvantage compared to larger producers integrated back to vinyl chloride and maybe chlorine. Hence, shut-down capacity at these smaller producers is more likely to remain closed this year and possibly never restart.

Besides the expected demand improvement in the construction market, some upturn will come in the many other uses, such as consumer products, electrical items, and packaging. However, none will outdistance construction in percentage growth.

The export market, which last year took about 10% of production, is expected to fall in 1983. One big reason is higher prices, up from bargain levels in 1982. Offsetting PVC exports for integrated producers may be an increase in exports of the polymer precursors, ethylene dichloride and vinyl chloride.

Without much help from exports, in 1983 PVC will ride largely on the fortunes of the U.S. construction business. Basics have impoved a lot here, but benefits for PVC will take a while, especially on the bottom line.

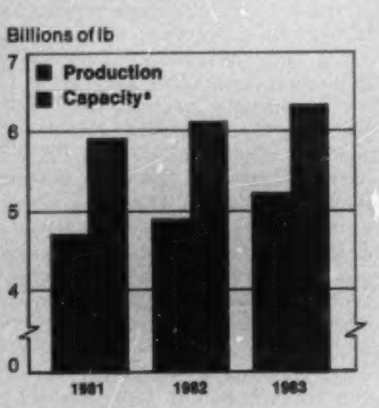
Key Polymers

High-density polyethylene

$-\!\!\left[CH_2-CH_2\right]_n\!\!-$

- ***Demand steadily up***
- ***Capacity rising***
- ***Prices still low***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of ethylene catalyzed by metallic salts and alkyls

MAJOR FABRICATED FORMS (U.S.)

Blow molding, mainly containers, 40%; injection molding 25%; pipe and conduit 10%; film and sheet 10%

FOREIGN TRADE

Exports—may fall below 600 million lb in 1983, imports—50 million lb

PRICES

List prices 45 cents per lb and up; discounts extensive

COMMERCIAL VALUE

$1.8 billion for production, 1983

Once again, high-density polyethylene provides some of the better news in the plastics world and retains its reputation as one of the best plastics businesses. In fact, it was the only one of the five major thermoplastics to increase production in 1982. And this year, it will be one of the few with sizable new investment.

Industry estimates put 1982 high-density polyethylene production at 4.9 billion lb, up 4% from 1981. For 1983, this steady growth will continue. Citing relatively large gains in production in late 1982, industry sources are even more optimistic for 1983, putting growth at 300 million to 500 million lb, or 6 to 10%, for a possible total of 5.4 billion lb.

In 1982, high-density polyethylene evaded the production drop in other thermoplastics largely on the strength of a more than 200-million-lb jump in exports. U.S. markets, notably the large container business for outlets such as gallon milk bottles, were about flat overall. For 1983, the growth pattern is due to switch, with a drop in exports and a gain at home.

As with other plastics, inventory forces are expected to influence production of high-density polyethylene in 1983. On one hand, producers with the capability of switching between high-density polyethylene and linear low-density polyethylene may raise inventories of high-density material temporarily and switch over, selling high-density from inventory for a while. This could put a slight damper on the year's overall production growth in high-density polyethylene. On the other hand, other producers adding capacity this year will need to build inventories to meet sales needs, thereby raising overall high-density polyethylene production.

Additional capacity coming on stream during 1983 will total more than 500 million lb per year. The dominant addition, about 450 million lb, is due to start up in the third quarter at Du Pont's plant near Bay City, Tex. Other capacity additions include American Hoechst's at Bayport, Tex., for ultrahigh-molecular-weight, high-density polyethylene, with capacity of 30 million lb a year. The unit is due on stream this month.

Excluding production from this new capacity, operable plants will have to run over 80% of capacity if 1983 production is to reach 5.2 billion lb. Including some production from new capacity, the operating rate still would remain close to 80%, the highest level for all major thermoplastics in 1983. High-density polyethylene certainly will top 80% if production surges to the levels proposed by its more optimistic analysts. For 1984, even with the added capacity in 1983, plant operations probably will do at least as well if the business recovery continues as expected.

Because some existing capacity can be shifted between high-density and linear low-density polyethylene, questions arise about operating rates required of other plants that cannot be switched. This high-density capacity might have to run higher than anticipated, according to some analysts, if demand for linear low-density polyethylene is strong. Of course, no resulting supply problems are in store for high-density polyethylene customers.

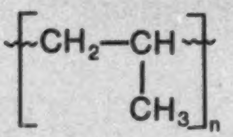
All these customers' major uses of high-density polyethylene now appear caught up in the business recovery. Use in injection molding, one quarter of the overall market, may be growing somewhat faster than other areas. A few very small uses also may exceed the average growth rate for the large blow-molding (container) market and other areas.

Exports are expected to slow down in 1983, in part as a result of the strong dollar and a lagging business recovery abroad. Exports climbed strongly in 1982 to a new high point, 14% of production. However, such performance isn't expected again.

The resulting damper on exports has the same effect on high-density polyethylene as does the moderate recovery at home—low profitability. List prices for most high-density grades haven't moved significantly in the past year, and neither have actual selling prices other than to reflect aberrations in raw material ethylene prices. The price calm hasn't done much for profits, and little improvement is expected for 1983 even with increased sales volume. In this respect, high-density polyethylene hasn't pulled out of thermoplastics' rut even though in many other ways it is one of the most attractive polymers.

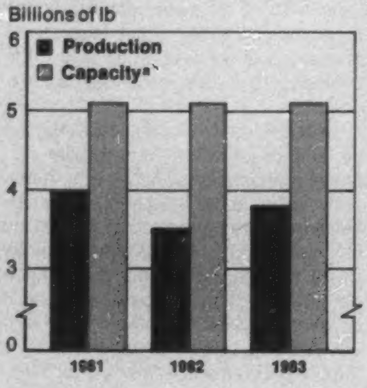
Key Polymers

Polypropylene


$$\left[\begin{array}{c}-CH_2-\underset{\displaystyle CH_3}{\underset{|}{CH}}-\end{array}\right]_n$$

- ***Demand mending***
- ***Capacity flat***
- ***Prices discounted***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of propylene catalyzed by metallic salts and alkyls

MAJOR FABRICATED FORMS (U.S.)

Injection molding 40%, fibers 30%, film 10%

FOREIGN TRADE

Exports—declining to about 700 million lb in 1983, imports—about 10 million lb

PRICES

List prices 42 cents per lb and up; discounting large

COMMERCIAL VALUE

$1.3 billion for production, 1983

Polypropylene was shaken badly by the recession, which for the moment has undercut all the glowing forecasts of the late 1970s for this plastic. Production fell about an eighth in 1982 from the record in 1981 and will recover so slowly that another year will be needed to reach new highs. That's bad news for all the companies that have poured new-entry or expansion money into polypropylene since 1975. At the moment, the investment wave is over, but the resulting overbuilt capacity keeps prices at unprofitable levels.

A combination of slumps in two key markets for polypropylene—autos and housing—and abnormally high costs of feedstock propylene for much of 1982 dropped production to less than 3.5 billion lb, off 12% from 1981. Sales in 1982 dropped only half as much as production, suggesting that inventories were pulled down more than 200 million lb.

This inventory drop could set the stage for a relatively stronger recovery in 1983 for polypropylene than for the polyethylenes. Production could increase 8% this year to about 3.8 billion lb, still below the 1981 high of about 4 billion lb. Some industry sources, however, doubt such a gain will occur, noting that at year end 1982 polypropylene's pickup was slower than for the polyethylenes. These analysts fear that polypropylene will struggle through 1983 with just a 5% gain, giving production of 3.7 billion lb or less.

In any event, U.S. polypropylene plants will run no higher than 75% of nameplate capacity on average this year. If production sticks at the pessimistic level, the operating rate will just break 72%.

Such relatively low operating rates for a polyolefin are the direct result of the capacity bulge in the late 1970s. Investment incentive is now zero and capacity has been almost flat for three years. No expansions will come on stream during 1983 either, other than the usual small gains from catalyst improvements and other process efficiencies. These gains might total 50 million lb among several polypropylene producers.

Other than exports, the big outlets for polypropylene all fell hard in 1982. Use in fibers, for example, declined almost a sixth from 1981. Fibers felt the decline in housing and in furnishings such as carpet and curtains. This fibers market, some 30% of U.S. polypropylene demand, probably will trail the current upturn in housing because of the lag time in ordering. The second half of 1983 could bring higher fiber use after carpet demand sops up large carpet inventories rumored to be held by manufacturers and dealers.

In general, the injection molding uses of polypropylene, some 40% of total U.S. consumption, were hit hard by the recession. These markets involve autos, appliances, toys, housewares, and many others. Recovery for these items will be spotty in 1983. Autos, for example, have posted smaller sales gains for the first quarter than analysts forecast. Such gains, plus the trend toward smaller cars, will result in little growth for polypropylene in this complex area in 1983. Appliance demand is doing better, along with demand for other consumer products that contain molded polypropylene. These uses could rise 10 to 15% in 1983, but they still will not get back to 1981 levels after declines exceeding 20% in 1982.

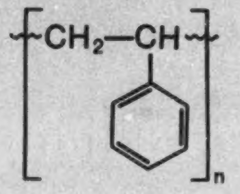
Exports were the brightest outlet for polypropylene in 1982, rising 8% to 740 million lb. However, the strength of the dollar and competition in world markets from producers in other countries are expected to pull exports below 700 million lb this year. The drop could be worse under the impact of declines in oil prices benefiting foreign producers.

Other major polypropylene markets in general are expected to aid the plastic's recovery. For example, high hopes exist in some quarters for polypropylene film, whose demand held up better in 1982. However, other opinion holds that film will have steady but not spectacular growth even though developmental work may overcome problems such as heat sealing.

Overall, polypropylene so far in the 1980s has failed producers' fond forecasts of the late 1970s. Even with a moderate upswing in demand this year, plant use and profitability will remain disappointing. Producers still have hopes for polypropylene and are pushing new-use development and downstream investment, but a big payoff is unlikely in 1983.

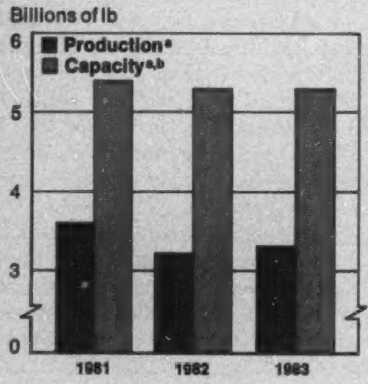
Key Polymers

Polystyrene



- ***Demand upturn small***
- ***Capacity flat***
- ***Prices very low***

PRODUCTION/CAPACITY



a All forms. b First quarter.

HOW MADE

Polymerization of styrene using a peroxide initiator

MAJOR FABRICATED FORMS (U.S.)

Injection molding 45%, extrusions 35%, expandable beads 15%; one third of end markets in packaging

FOREIGN TRADE

Exports—pushing to more than 100 million lb in 1983, imports—less than 10 million lb

PRICES

List prices 45 cents per lb and up; discounting large

COMMERCIAL VALUE

$1.2 billion for production, 1983

The polystyrene business is stirring this year, but that doesn't mean it's much better off. This is still the thermoplastic with the biggest headaches for producers—falling markets, low plant use, and no profit.

Production and sales of polystyrene will turn up in 1983, but less than for any of the other major thermoplastics. Instead, the main events for this polymer will be plant operating and ownership changes.

This producer shuffle and the possible permanent shutdown of some small plants reflect polystyrene's general malaise. Production in 1983 is expected to grow about 100 million lb, or just 3%, from 1982 to reach 3.3 billion lb. Packaging uses may lead the way.

This isn't much of a bounce, however, after a 1982 output level 11% below 1981 and 20% below the peak of 4.0 billion lb in 1979. The decline of the past three years and meager recovery expected in 1983 clearly show what polystyrene producers' problems come down to and why capacity is expected to decline. With the production slump, surplus capacity has put heavy pressure on selling prices, ruining profitability.

Polystyrene capacity definitely will shift. Some producers are adding to expandable bead capacity, but not all of this capacity will operate. At Mobil Chemical, polystyrene capacity is slated to increase 260 million lb per year in the second half of 1983 at Joliet, Ill. The expansion is in two units, one for 160 million lb per year of crystal polystyrene and the other for 100 million lb per year of high-impact polystyrene.

Overall, some polystyrene capacity now may be shut down for good, even though the owners have not yet indicated that these units will be scrapped, and so they are still included in capacity totals.

On paper then, given nameplate capacity of 5.3 billion lb per year, polystyrene will suffer an operating rate of just 62% in 1983 after 60% in 1982. These are the lowest rates among major thermoplastics.

If 5 to 10% of nameplate capacity is shut down at least temporarily, the operating rate for remaining capacity improves to 65 to 70%. But even at these rates, price pressure will keep profitability low and shutdown incentive high.

Not that polystyrene producers have given up trying to improve profitability. They have tried again and again to raise prices, only to be thwarted by one factor or another. For example, earlier this year, they rolled out a price increase of 2 cents a lb for most of the U.S. and 3 cents a lb for west of the Rockies. Asked what happened to the increase, one industry marketer simply says: "It's time to try again." At present, a higher spot price for raw material benzene might help lever a polystyrene price increase to reverse the squeeze in value between the two chemicals.

The root of polystyrene's financial problems is that it is a mature product largely on the defensive. It has only slow growth in old markets, where it dominates, and plenty of competition from other polymers in both these and newer markets. Seeing such limited growth prospects, some companies like Shell Chemical have gotten out of the business or are considering such a move. An upturn in polystyrene in 1983 and 1984 may put these exit plans on the shelf, but some analysts still expect permanent shutdowns of small plants.

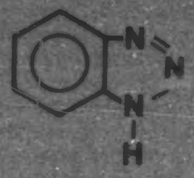
The 1981–82 recession hit polystyrene's uses across the board except for expandable beads, a product with some investment behind it. The recession hit polystyrene's major outlets in manufactured goods hard, and there was little polystyrene producers could do about it. Packaging, consumer goods such as toys, and electronic uses all fell badly. Innovations in these areas to increase polystyrene demand are limited and hard to justify for a product showing little or no return on investment.

Exports, an important aid to demand for other thermoplastics, are relatively small for polystyrene. Polystyrene exports dropped more than a third in 1982 to less than 100 million lb. They are forecast to recover somewhat in 1983 but probably not back to the 1981 level of 150 million lb. Longer-term prospects for exports are flat to slightly down.

Without much hope abroad, polystyrene is boxed into a declining U.S. market. It may not do much better than stabilize itself this year, and some plant owners' patience may run out.

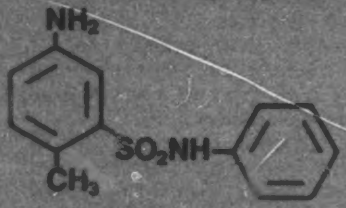
SANDOZ
Organic
Intermediates

Benzotriazole



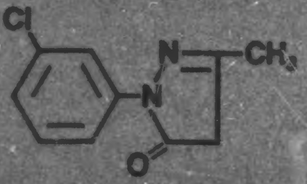
MW 119 CAS 95-14-7

1-Amino-4-methylbenzene-3-sulphonic acid-N-phenylamide



PTSL MW 262 CAS 79-72-1

1-(3′-Chlorophenyl)-3-methyl-5-pyrazolone



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CIRCLE 49 ON READER SERVICE CARD

Chemical firms rank high in information services

Years ago, recalls Eugene B. Jackson of the University of Texas, Austin, the vice president for R&D of a major metals-based firm told Jackson that he did not wish to determine, or even to know, the cost of information services in his corporation—"as it is below the nuisance level."

"Those days are gone forever, and the million-dollar-plus industrial information system is very much with us," Jackson observes. Moreover, he points out, chemical firms lead or rank high compared to other industrial groups in most categories related to information services that he has measured; the pharmaceutical industry also ranks high.

Thus, chemical firms lead in number of libraries, number of companies with international library systems, number of professional librarians, ratio of libraries to employees, and library penetration (a measure of company spending on information services). And these results exclude chemical libraries at pharmaceutical, petroleum refining, food, rubber, and other chemical-related firms. Jackson, a professor at Texas University's graduate school of library and information science, outlined his estimates of chemical industry spending on technical information services at the Symposium on the Cost of Providing Information from an Industrial Information Center, held by the Division of Chemical Information at the American Chemical Society national meeting in Seattle.

Jackson calculates that 120 libraries and technical information centers run by chemical firms in the *Fortune* 500 spend well over $50 million a year. It appears, he notes, that the chemical industry spends about 2% of its R&D budget for technical information services.

Of the $50.7 million spending that he can assign to specific budget categories, the biggest portions go to personnel costs ($18.2 million, 36%) and materials ($17.3 million, 34%). As

Top four companies spend almost half of chemical industry outlays for information services

Extended budget, $ thousands[a]	Top four firms	Other firms	All firms
Personnel	$ 9,164	$ 9,037	$18,201
Managerial, professional[b]	4,620	4,883	9,503
Nonprofessionals[b]	3,734	3,201	6,935
Travel	270	313	583
Continuing education	540	640	1,180
Materials	8,813	8,457	17,270
Books, monographs[c]	3,756	3,339	7,096
Periodicals, serials[c]	3,532	3,464	6,997
Government documents, maps, patents	939	835	1,774
Photocopies	420	588	1,008
Document delivery products	165	231	396
Services	4,916	6,348	11,264
On-line bibliographic and numeric reference services	2,610	3,150	5,760
On-line technical processing	300	420	720
Binding of periodicals	100	140	240
Computer system support	1,250	1,750	3,000
Telephone and telecommunications	92	99	191
Records management	564	789	1,353
Facilities[d]	1,564	2,262	3,826
Supplies: technical processing	50	70	120
TOTAL	**$24,507**	**$26,174**	**$50,681**

a Data include estimated budgets for libraries and technical information centers for top four chemical firms in all categories, and for 25 other chemical firms from the "*Fortune 500*" for most categories (three categories include data from only 20, 21, or 22 "other firms"). b Including fringe benefits. c Including permanent retention. d Including utilities, janitorial services, and minor repairs. **Note:** Data do not include budget categories that could not be estimated; for example, temporary assistance, external and internal research reports, on-line "high ticket" marketing information services, publications and dissemination services, word processing services, competitor analysis services, and records management off-site. **Source:** Eugene B. Jackson, University of Texas, Austin might be expected, the largest single category is managerial and professional salaries and fringe benefits ($9.5 million), followed by the costs of books and monographs ($7.1 million), periodicals and serials ($7.0 million), nonprofessional salaries and fringe benefits ($6.9 million), and on-line bibliographic and numeric reference services ($5.8 million). The four largest chemical firms in the U.S.—Du Pont, Union Carbide, Monsanto, and Dow Chemical—together spend almost as much on their 50 information centers as all the others do on their 70 centers.

Jackson notes that his estimates are considerably larger than would be derived from just "conventional budget" items. He calculates instead an "extended budget," including real costs of supplying technical information services that are rarely or never included in conventional budgets, such as staff fringe benefits, costs for permanent retention of books and periodicals, and computer system support.

Indeed, he points out, his estimates are still too low because he could not estimate costs for a number of important budget categories such as temporary assistance, external and internal research reports, and on-line "high ticket" marketing information services. Moreover, the data available did not enable him to make estimates for all categories for several firms, and a few firms had to be excluded completely. In addition, chemical firms not in the *Fortune* 500 were not included.

Jackson points out that chemical industry budgets for information services are generally considered proprietary and are not revealed. His deductions are made by combining data, inferences, and extrapolations from open sources, such as standard directories of information centers and their staffs, professional society salary surveys, indexes of literature materials and services costs, and reports of corporate R&D spending. Instead of such extrapolations, he urges adoption of a mechanism for systematically and confidentially compiling data from chemical firms. However, Jackson's approaches to the Chemical Manufacturers Association and others about setting up a clearinghouse have so far not borne fruit. ☐

CHECKOFF

NEW PLANTS

■ **Carbon fibers.** Great Lakes Carbon will build plant in Roane County in Tennessee to produce 800,000 lb per year of these fibers, with design to add capacity as use warrants. Completion due in 1984.

■ **Fungicide.** Uniroyal Chemical will build unit in Naugatuck, Conn., to make Vitavax, its proprietary systemic fungicide used on seeds of small grains. Timetable for construction and capacity of plant was not disclosed.

■ **Industrial gases.** Airco Industrial Gases has begun construction on 465-ton-per-day air separation plant in Aiken, S.C., which will cost more than $15 million and be completed in summer of 1984.

■ ***p*-Xylene.** Chevron Chemical plans to expand capacity of unit at Pascagoula, Miss., to 500 million lb per year from present 430 million lb of this raw material for polyesters. Cost is not disclosed for project, to be completed by end of 1984.

■ **Specialty inorganics.** Calabrian Chemicals will build units to make sodium thiosulfate and sulfamic acid at its plant in Port Neches, Tex., with completion due in second-quarter 1983; capacities and cost were not disclosed.

■ **Thioglycolic acid.** M&T Chemicals, wholly owned subsidiary of Elf Aquitaine of France, will build plant at company's Mobile, Ala., site to make 4000 metric tons per year of this intermediate used in producing stabilizers for polyvinyl chloride and in cosmetic ingredients. Completion of multimillion dollar unit is slated for fourth quarter of 1984.

PLANTS COMPLETED

■ **Ethylene.** Arco Chemical has started up first of two cracking furnaces designed by M. W. Kellogg that increase output and efficiency. When second furnace is on stream, Arco Chemical's ethylene capacity at Channelview, Tex., plant will be 2.4 billion lb per year.

■ **Sulfuric acid.** Conserv, the phosphate fertilizer subsidiary of Phibro-Salomon, dedicated its new sulfuric acid plant at Nicholas, Fla., last month. Plant can produce 730,000 tons per year of acid and cogenerates 13 MW of electricity.

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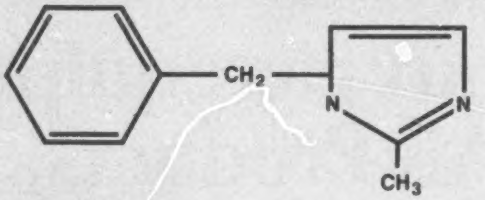

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CIRCLE 42 ON READER SERVICE CARD

Industry Project Aims at Cutting Federal Government Costs

Survey is examining all government operations; most recommendations call for management-level changes, some paring of R&D budgets

One of President Reagan's goals is to improve the efficiency of the federal bureaucracy. And a major effort to get a handle on this problem is the Private Sector Survey on Cost Control. Set up in June 1982, this large project is headed by W. R. Grace chairman J. Peter Grace and is being staffed and funded entirely by private industry.

Grace assembled 163 executive committee members for the survey from the nation's leading corporations, who in turn recruited 1300 task force volunteers. These workers aim to produce 38 reports on all segments of the federal government, looking at ways to cut costs by changing management practices and improving efficiency. The entire project is expected to cost about $50 million, all of which will be paid for by private contributions.

Grace says this project differs from others bent on finding ways to improve the federal government. "From the beginning, the concept of the survey was unique in its approach," he says. "Our effort was more massive and involved a tremendous amount of expertise. . . . I don't think anything like it has been done before."

The first six reports already have been released. Most of the departments studied have research and development budgets. The reports are on the departments of Commerce, Agriculture, Health & Human Services, and Energy (combined with the Nuclear Regulatory Commission), and the Environmental Protection Agency (combined with the Small Business Administration and the Federal Emergency Management Agency). Recommendations concern all levels of agency activities, but most of them deal with management-level changes. Still, the R&D areas are not immune to some paring.

Grace: survey is unique in approach

C&EN staff photo

Some of the more major changes are recommended for DOE research. Dollar savings are not listed for some of the changes, but if implemented they would change how the department does research. Primarily, the Cost Control Survey recommends that more independence be given to the directors of the national laboratories. A multiyear rolling budget for research would give them that autonomy, but, the survey argues, that leads to another problem. The labs lack direction. The survey finds a serious need for an authoritative and specific outline on an overall R&D mission for the national labs, something that apparently has not been done. This would eliminate the duplication of efforts found at some labs and help eliminate "some unseemly competition for funds among the R&D operations" at DOE.

Other recommendations include a critical look at DOE funding of the Clinch River breeder reactor and of the full-blown gas centrifuge enrichment plant. Support of these projects is in conflict with established DOE policy of not funding existing technologies that are ready for commercialization, the report says, noting that several billion dollars could be saved if they were dropped.

In another item, the survey shows that the government could save about $1.25 billion by relieving itself of management of the Strategic Petroleum Reserve and making it a government-owned, contractor-operated facility.

DOE's military projects also were scrutinized. One recommended change is that the U.S. "take the technologically feasible but psychologically troublesome step" of using civilian nuclear power reactors as a source of radionuclides to replace those that decay in nuclear warheads over time.

Major changes also are recommended for EPA. For R&D, it recommends that eight of the agency's 14 regional labs be closed. These are small facilities, usually with fewer than 20 employees, that the survey argues are not adequate to handle the increasing demand for analysis of trace substances in toxic waste site samples. The survey also finds that EPA could get more research out of its depleted R&D budget if it would increase the number of cooperative agreements between its labs and if a long-term plan for research were developed.

Much of the EPA savings would come from completing the transfer of duties to state agencies. The biggest saving, about $15 million, would come from complete transfer of the National Pollution Discharge Elimination System permit program to the states. Several states do not have EPA-approved programs, and unless they get them soon, the survey recommends EPA drop grants from this program to those states. Presently, in addition to EPA's approving the permits, the states use the grants for their own, duplicate process, creating a dual permitting system, both financed by the federal government.

Commerce's National Bureau of Standards came in for some careful examination. The survey found that 20 to 30% of the programs being done at NBS are not part of the agency's original mission and could be taken over by private companies. These include projects mostly in the areas of chemical engineering, manufacturing engineering, fire research, building technology, analytical chemistry, and materials science.

The research recommendations for HHS and USDA are somewhat related. The survey makes no suggestions to cut support for the National Institutes of Health or for most agriculture research. But it finds that the nutrition centers supported by the Agriculture Research Service could be eliminated, as they appear to duplicate the much larger and better funded nutrition programs at NIH. There also are about 20 programs of the Cooperative State Research Program that could be eliminated and/or taken over by the private sector. Most of those are marketing programs, tracking foreign agriculture developments, or consumer-oriented information programs.

All the changes recommended for research are overwhelmed by the changes sought in personnel practices for federal workers. Changes in the civil service retirement system could save more than $15 billion in the first year, the survey calculates. Other changes in federal health benefits, annual leave, sick leave, and pay comparability that would bring the federal government more in line with practices of the largest private companies would save up to $35 billion in just three years.

Trimming federal employee benefits gives greatest savings

$ Millions	1st Year	2nd Year	3rd Year	Total
Agriculture Department	$ 2,458.5	$ 2,883.5	$ 3,217.5	$ 8,559.0
Commerce Department	33.0	52.5	60.3	145.8
Energy Department/Nuclear Regulatory Commission	548.0	826.9	903.6	2,278.5
Environmental Protection Agency/ Small Business Administration/ Federal Emergency Management Administration	357.4	541.9	610.8	1,510.1
Health & Human Services Department	129.9	173.4	190.9	494.2
Personnel benefits	10,219.9	11,533.8	12,972.1	34,725.8
TOTAL	$13,746.7	$16,012.0	$17,954.7	$47,713.4

Note: These savings represent only those amounts for which the survey believes it can fully support the recommended changes. Source: President's Private Sector Survey on Cost Control

Public meetings on these and the other cost-control survey reports will be held over the next couple of months. All the reports are expected to be completed and sent to the President this summer. The biggest question is how many of the thousands of recommended changes will be tried.

Grace says that for some agencies, as many as 90% of the recommendations can be carried out by the agency heads on their own. In all, about 40% of the suggestions would require Congressional action to implement them.

Reagan had a similar survey done when he was governor of California and tried to put about 70% of the suggested changes into practice there. Grace is confident most of this cost-control survey will be tried as well, but seasoned observers say they have seen other well-meaning efforts to control the government come to very little. □

1984 budget favors research at universities

The outlook in the Administration's proposed budget for fiscal 1984 is quite favorable for basic research in chemistry—in particular, research conducted at academic institutions. In contrast, the chemistry work that is incidental to missions of federal agencies would not fare as well.

These are the conclusions presented in the American Association for the Advancement of Science's preliminary analysis of R&D in the fiscal 1984 budget. The chapter on chemistry was prepared by Le-Nhung McLeland and Annette T. Rosenblum of the American Chemical Society's Department of Public Affairs, who ferreted out details on chemistry funding not readily available in the Administration's formal budget proposals (C&EN, Feb. 7, page 9).

For the Department of Defense, the report says, it is assumed that funding for basic research in chemistry and materials will increase 12.7%, the same as the overall increase for basic research, but it is possible that chemistry and materials will receive a larger share of the increase, as was the case last year. The report notes that two areas of DOD emphasis that involve considerable work in chemistry are development of advanced composite materials and chemical defense, where plans are afoot to develop vaccines and therapeutics for chemical/biological defense. DOD reports that the university contract base in the chemical defense program has doubled recently.

At the Department of Energy, the report notes, proposed funding for the geosciences program includes an increase of about $400,000 for geochemistry research—geomigration and organic geochemistry. However, the proposed budget for environmental R&D is expected to force reductions in all ongoing programs, including research on dry (acid) deposition and measurement of toxic agents generated by energy opera-

Chapel Hill, Berkeley head graduate rankings

The University of North Carolina, Chapel Hill, remains the nation's largest producer of bachelor's degree chemistry graduates. And the University of California, Berkeley, has displaced the University of Illinois, Urbana-Champaign, as the biggest producer of Ph.D. chemistry graduates for the second time in the past nine years.

These are two of the findings from C&EN's analysis of the mass of data contained in the latest annual report of ACS's Committee on Professional Training. This committee is the mechanism through which ACS sets standards for and monitors undergraduate chemistry education. The committee also gathers data from the more than 500 schools with undergraduate programs it has approved on chemistry graduations at all levels. (The text of the committee's latest report covering the 1981-82 academic year starts on page 70.)

Chapel Hill has been the largest producer of bachelor's degree chemists for eight of the past nine academic years. It was dislodged by Indiana University in 1979-80 but regained the lead the following year, pushing Indiana down to second. Indiana retains the second spot in the latest report.

The top spot among the producers of Ph.D. chemists has alternated between Berkeley and Urbana-Champaign for the past four years. In the latest report, Urbana-Champaign has to settle for second place.

For the first time in eight years, the University of California, San Diego, is not the largest producer of certified bachelors graduates. Instead, it slips to second place, behind Rutgers University. Such graduates have completed a curriculum certified by CPT and are immediately eligible for membership in ACS.

A total of 66 schools appear on at least one of the four listings in this article. These listings rank the 25 largest producers of bachelors graduates, certified bachelors graduates, M.S. graduates, and Ph.D. graduates. Only three schools—San Diego, Urbana-Champaign, and UCLA—appear on all four lists. □

These schools had the most chemistry graduates, 1981–82

Total bachelors graduates

1.	U of North Carolina, Chapel Hill	136
2.	Indiana U	134
3.	U of Illinois, Urbana-Champaign	131
4.	U of Maryland	106
5.	U of Pittsburgh	104
6.	U of California, Los Angeles	99
7.	Rutgers U, New Brunswick	85
8.	U of Virginia	83
9.	Emory U	82
10.	Duke U	77
11.	U of South Florida	76
12.	Miami U	72
13.	U of California, San Diego	70
14.	U of Miami	68
15.	U of Washington	65
16.	State U of New York, Stony Brook	64
17.	California Polytechnic State U	62
17.	U of Florida	62
19.	St. Louis U	59
20.	U of California, Berkeley	58
21.	U of Colorado, Boulder	56
22.	West Virginia U	51
23.	Creighton U	50
23.	U of Texas, Austin	50
25.	St. Olaf C	49

Certified bachelors graduates

1.	Rutgers U, New Brunswick	73
2.	U of California, San Diego	70
3.	U of Pittsburgh	60
4.	U of Illinois, Urbana-Champaign	54
5.	U of Texas, Austin	50
6.	U of California, Berkeley	46
6.	U of Washington	46
8.	U of Michigan, Ann Arbor	44
9.	Massachusetts Inst. of Tech	38
10.	Indiana U	37
10.	U of North Carolina, Chapel Hill	37
12.	C of William and Mary	36
13.	State U of New York, Stony Brook	33
13.	Rensselaer Polytechnic Inst.	33
15.	U of Cincinnati	32
15.	Illinois State U	32
17.	U of California, Los Angeles	31
18.	U.S. Naval Academy	30
19.	U of Delaware	29
20.	Stanford U	28
21.	U of Minnesota, Minneapolis	26
21.	Ohio State U	26
23.	Georgia Institute of Technology	25
24.	C of the Holy Cross	24
24.	Lehigh U	24

Masters graduates

1.	Cornell U	31
2.	U of Michigan, Ann Arbor	29
3.	Ohio State U	28
4.	Northwestern U	25
5.	Yale U	24
6.	U of Illinois, Urbana-Champaign	23
7.	Purdue U	22
8.	Harvard U	21
9.	U of California, San Diego	20
9.	Columbia U	20
11.	U of Cincinnati	19
11.	San Diego State U	19
13.	Lawrence U	18
13.	U of Rochester	18
15.	Rensselaer Polytechnic Inst.	17
16.	San Jose State U	16
17.	U of Illinois, Chicago	15
17.	Wright State U	15
19.	U of California, Los Angeles	14
19.	Illinois Institute of Technology	14
19.	Michigan State U	14
22.	U of California, Santa Barbara	13
22.	Lehigh U	13
22.	U of Missouri, St. Louis	13
22.	North Carolina State U	13
22.	Seton Hall U	13
22.	Stevens Institute of Technology	13
22.	U of Washington	13
22.	U of Wisconsin, Madison	13

Doctoral graduates

1.	U of California, Berkeley	66
2.	U of Illinois, Urbana-Champaign	60
3.	U of Wisconsin, Madison	50
4.	Massachusetts Inst. of Tech	36
4.	Michigan State U	36
6.	Purdue U	33
7.	U of California, Los Angeles	30
7.	Cornell U	30
9.	U of California, San Diego	29
9.	U of Texas, Austin	29
11.	Northwestern U	28
11.	Ohio State U	28
13.	Columbia U	27
14.	Harvard U	26
14.	U of North Carolina, Chapel Hill	26
16.	California Institute of Tech	25
16.	Pennsylvania State U	25
16.	U of Pennsylvania	25
19.	Indiana U	24
20.	Iowa State U	22
20.	U of Maryland	22
22.	U of Chicago	21
22.	Princeton U	21
24.	Stanford U	20
25.	U of Iowa	19
25.	U of Minnesota, Minneapolis	19

ACS Committee on Professional Training 1982 Annual Report

Summary of data from approved programs, 1978–82

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates	Non-certified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1978	547	10,350	4285	6065	323	1798	189	1532
1979	551	10,451	4424	6027	323	1716	188	1532
1980	554	10,170	4170	6000	324	1698	188	1561
1981	558	10,453	4337	6116	323	1609	187	1613
1982	561	9,866	4179	5687	322	1645	187	1683
CHEMICAL ENGINEERING[a]								
1978	119	4,225	4225	—	114	1109	98	251
1979	112	4,977	4977	—	107	951	92	237
1980	109	5,348	5348	—	105	974	88	243
1981	110	5,831	5831	—	106	1020	87	250
1982	113	5,963	5963	—	109	1171	92	293

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year. **NOTE:** Bachelor's degree projections for 1983: 561 chemistry departments report that they expect a total of 10,585 bachelor's degree graduates with majors in chemistry during the 1982–83 academic year, and 113 chemical engineering departments report that they expect a total of 6664 bachelor's degree graduates with majors in chemical engineering.

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 5.6% in the 1981–82 academic year from the previous year. The number of master's degrees from these departments rose 2.2%, and the number of Ph.D. degrees continued to rise for the third year in a row, this year 4.4%.

The percentage of baccalaureate graduates certified by ACS rose slightly from 41% to 42%. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2252 of the bachelor's degree graduates from the approved schools were reported as planning to go to graduate school and 1990 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1981–82 by departments whose chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (Note: Those departments are not required to report their data to CPT, so the number of departments included varies each year.) A new table with this year's report includes information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

Summary of totals from 1982 reports from approved programs

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, total	561	6861	3005	9866
Certified		2895	1284	4179
Noncertified		3966	1721	5687
Masters	322	1154	491	1645
Doctorates	187	1411	272	1683
CHEMICAL ENGINEERING				
Bachelors, certified	113	4636	1327	5963
Masters	109	1000	171	1171
Doctorates	92	279	14	293

The number of bachelor's degrees in chemical engineering from the 113 AIChE-ABET-accredited departments that reported in 1982 increased 2.3% from the total reported by 110 departments in 1981. These 113 departments reported an expected further increase of 12% in 1983.

During the five-year period from 1978 to 1982, the number of reported bachelor's degree graduates in chemical engineering increased 41%. At the graduate level, the number of

Committee members, 1982

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Henry A. Bent, *acting chairman, January to June*
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Alice J. Cunningham
Agnes Scott College
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Bonnie R. Blaser, *secretary*
Mairin B. Brennan, *staff associate*
American Chemical Society

Fall 1981 grad student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. departments[a]	135	448	366	1,073	1044
Ph.D. departments	187	3248	311	12,835	1518
TOTAL	322	3696	677	13,908	2562

[a] Departments whose highest offering is the master's degree in chemistry.

chemical engineering master's degrees reported in 1982 rose 15% from the year before, and the number of Ph.D. degrees reported increased 17%.

Programs at ACS-approved departments normally are re-evaluated at five-year intervals. There were 564 colleges and universities on the approved list at the end of 1982. The committee studied the chemistry programs at 153 of them during the year.

Each re-evaluation involved a review of extensive documentary materials submitted by the department head describing the current status of the program. During 1982, five chemistry programs were newly approved by the committee and two approved programs were put on probation. No departments were removed from the approved list in 1982.

During the year the committee continued its work in revising the criteria used to evaluate undergraduate programs in chemistry. Draft copies of the revision were sent to all of the ACS-approved schools, ACS divisions, and the CPT Visiting Associates, and open meetings to discuss the revision were held at both national meetings of the society last year.

Reports were prepared and disseminated on the committee's surveys on the use of computers in undergraduate chemistry programs and on the language requirements in graduate programs in chemistry. The committee conducted a second survey on the use of computers in undergraduate programs in the fall of 1982 and expects to prepare a report on this survey in 1983.

To determine why chemistry faculty members leave for other positions, especially nonacademic ones, the committee conducted a survey in 1980 on faculty mobility in the past 10 years (1970-79) in ACS-approved departments. To identify trends, followup surveys were conducted for the 1980 calendar year and again for 1981. The committee plans to continue these surveys and to prepare reports on faculty mobility in chemistry departments as trends are identified.

The committee agreed to include polymer and clinical chemistry programs in the 1983 edition of the ACS Directory of Graduate Research, a biennial publication that provides guidance information for students who are considering graduate education in chemistry and related fields. Currently the directory includes M.S.- and Ph.D.-degree granting departments of chemistry, chemical engineering, biochemistry, and pharmaceutical/medicinal chemistry in the U.S. and Canada. Included in each department's listing is biographical information on faculty members, their research interests, and titles of their publications for a two-year period.

Work continued on the development of the Directory of Graduate Research Concordance, a proposed computerized database of the names and research interests of faculty members included in the directory. It is planned that the database will be arranged in a hierarchical way so that it can be searched to yield information on faculty members who have expressed interest in any broad subject, or, on a reduced scope, to identify those with interests in exceedingly narrow disciplines. Because the database will be built on faculty lists in the 1983 directory, it will serve as a multilevel concordance for this volume.

Chemistry and chemical engineering degrees awarded by approved schools, 1981–82

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	4	2	0	—	—	—	—
Adelphi U	4	7	0	—	—	—	—
Agnes Scott C	3	0	—	—	—	—	—
Akron, U of	16	4	4	4	30	6	2
Alabama, U of							
University	2	12	3	4	28	3	2
Birmingham	9	10	6	1	—	—	—
Huntsville	3	6	3	—	—	—	—
Alaska, U of	1	0	2	—	—	—	—
Albion C	5	24	—	—	—	—	—
Albright C	6	11	—	—	—	—	—
Alfred U	7	0	—	—	—	—	—
Allegheny C	0	36	—	—	—	—	—
Alma C	2	5	—	—	—	—	—
American U	4	0	6	5	—	—	—
Amherst C	3	6	—	—	—	—	—
Andrews U	7	9	—	—	—	—	—
Appalachian State U	1	8	0	—	—	—	—
Arizona State U	16	8	2	14	36	9	0
Arizona, U of	14	18	6	15	29	9	3
Arkansas, U of							
Fayetteville	3	16	3	11	42	4	1
Little Rock	5	6	2	—	—	—	—
Ashland C	2	3	—	—	—	—	—
Auburn U	4	28	5	5	74	7	0
Augsburg C	0	8	—	—	—	—	—
Augustana C (Illinois)	0	9	—	—	—	—	—
Augustana C (South Dakota)	0	6	—	—	—	—	—
Austin C	3	8	—	—	—	—	—
Baldwin-Wallace C	0	6	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Ball State U	7	1	6	—	—	—	—
Barnard C	3	8	—	—	—	—	—
Bates C	4	11	—	—	—	—	—
Baylor U	20	19	0	2	—	—	—
Beloit C	1	12	—	—	—	—	—
Bemidji State U	4	4	—	—	—	—	—
Birmingham-Southern C	3	14	—	—	—	—	—
Bloomsburg State C	1	5	—	—	—	—	—
Boston C	11	27	5	2	—	—	—
Boston U	1	16	5	3	—	—	—
Bowdoin C	2	34	—	—	—	—	—
Bowling Green State U	3	22	9	—	—	—	—
Bradley U	1	11	—	—	—	—	—
Brandeis U	0	8	9	9	—	—	—
Bridgeport, U of	4	1	7	—	—	—	—
Bridgewater State C	3	8	0	—	—	—	—
Brigham Young U	19	23	2	5	39	6	0
Brown U	1	26	5	10	—	—	—
Bryn Mawr C	14	0	0	0	—	—	—
Bucknell U	9	15	4	—	36	1	—
Butler U	5	8	2	—	—	—	—
California Institute of Tech	5	5	3	25	15	10	9
California Polytechnic State U	22	40	2	—	—	—	—
California State C							
Bakersfield	5	1	—	—	—	—	—
San Bernardino	2	3	—	—	—	—	—
Stanislaus	3	2	—	—	—	—	—
California State Polytechnic U	11	10	3	—	a		
California State U							
Chico	2	12	—	—	—	—	—
Dominguez Hills	11	4	—	—	—	—	—
Fresno	7	2	3	—	—	—	—
Fullerton	17	16	4	—	—	—	—
Hayward	12	19	1	—	—	—	—
Long Beach	13	25	8	—	a		
Los Angeles	10	1	5	—	—	—	—
Northridge	12	9	2	—	—	—	—
Sacramento	11	9	4	—	—	—	—
California, U of							
Berkeley	46	12	11	66	133	27	13
Davis	19	3	5	7	40	13	2
Irvine	13	31	4	10	—	—	—
Los Angeles	31	68	14	30	—	—	—
Riverside	14	0	6	9	—	—	—
San Diego	70	0	20	29	—	—	—
Santa Barbara	12	7	13	9	47	6	3
Santa Cruz	20	5	0	1	—	—	—
Calvin C	3	5	—	—	—	—	—
Canisius C	3	4	—	—	—	—	—
Capital U	0	9	—	—	—	—	—
Carleton C	11	12	—	—	—	—	—
Carnegie-Mellon U	19	2	6	3	83	21	10
Carroll C	1	3	—	—	—	—	—
Carthage C	2	5	—	—	—	—	—
Case Western Reserve U	11	21	9	6	49	8	1
Catholic U of America	5	2	3	1	4	2	0
Centenary C of Louisiana	0	3	—	—	—	—	—
Central C	1	4	—	—	—	—	—
Central Connecticut State C	8	0	3	—	—	—	—
Central Florida, U of	22	0	3	—	—	—	—
Central Michigan U	1	15	3	—	—	—	—
Central State U							
Wilberforce, Ohio	4	4	—	—	—	—	—
Edmond, Okla.	0	10	—	—	—	—	—
Charleston, C of	10	2	—	—	—	—	—
Chatham C	1	1	—	—	—	—	—
Chestnut Hill C	0	7	—	—	—	—	—
Chicago, U of	4	30	4	21	—	—	—
Cincinnati, U of	32	0	19	16	70	13	0
Citadel, The	2	9	—	—	—	—	—
City U of New York							
Graduate Center	—	—	—	7	—	—	—
Brooklyn C	1	34	1		—	—	—
City C	0	14	3		27	4	2
Herbert H. Lehman C	1	4	—		—	—	—
Hunter C	3	16	0		—	—	—
Queens C	7	21	3		—	—	—
Clarion State C	3	2	—	—	—	—	—
Clark U	17	0	0	3	—	—	—
Clarkson C of Tech	22	0	1	5	130	5	2
Clemson U	7	3	4	3	56	8	1
Cleveland State U	17	0	11	1	61	7	0
Coe C	1	5	—	—	—	—	—
Colby C	4	11	—	—	—	—	—
Colgate U	1	20	—	—	—	—	—
Colorado C	9	4	—	—	—	—	—
Colorado School of Mines	3	0	10	2	75	11	2
Colorado State U	22	14	2	11	24	7	—
Colorado, U of							
Boulder	12	44	6	17	67	10	2
Denver	2	6	0	—	—	—	—
Columbia U	9	32	20	27	42	31	6
Concordia C	4	12	—	—	—	—	—
Connecticut, U of	16	15	5	3	49	9	0
Cooper Union[b]	—	—	—	—	29	6	—
Cornell C	0	12	—	—	—	—	—
Cornell U	23	20	31	30	72	20	4
Creighton U	4	46	2	—	—	—	—
Dartmouth C	0	25	1	4	—	—	—
David Lipscomb C	2	17	—	—	—	—	—
Davidson C	9	1	—	—	—	—	—
Dayton, U of	5	7	3	—	50	2	—
Delaware State C	0	3	—	—	—	—	—
Delaware, U of	29	15	10	9	57	19	11
Delaware Valley C of Science & Agriculture	5	0	—	—	—	—	—
Delta State U	3	9	2	—	—	—	—
Denison U	2	4	—	—	—	—	—
Denver, U of	8	12	4	2	—	—	—
De Paul U	1	0	5	—	—	—	—
DePauw U	4	9	—	—	—	—	—
Detroit, U of	7	2	6	2	14	10	5
Dickinson C	7	12	—	—	—	—	—
Drake U	2	7	—	—	—	—	—
Drew U	1	14	—	—	—	—	—
Drexel U	16	0	11	5	79	6	1
Duke U	15	62	6	11	—	—	—
Duquesne U	4	10	3	1	—	—	—
Earlham C	0	4	—	—	—	—	—
East Carolina U	6	10	3	—	—	—	—
East Stroudsburg State C	4	11	1	—	—	—	—
East Tennessee State U	5	5	4	—	—	—	—
East Texas State U	2	1	3	—	—	—	—
Eastern Illinois U	6	4	4	—	—	—	—
Eastern Kentucky U	5	10	2	—	—	—	—
Eastern Michigan U	1	28	2	—	—	—	—
Elizabethtown C	0	15	—	—	—	—	—
Elmhurst C	1	7	—	—	—	—	—
Emory U	9	73	9	14	—	—	—
Emporia State U	0	3	3	—	—	—	—
Evansville, U of	3	4	—	—	—	—	—
Fairfield U	9	7	—	—	—	—	—
Fairleigh Dickinson U							
Florham-Madison[c]					—	—	—
Rutherford	3	0	3	—	—	—	—
Teaneck	3	0	2	—	—	—	—
Fisk U	10	0	2	—	—	—	—
Florida Atlantic U	4	19	1	0	—	—	—
Florida State U	8	14	9	12	—	—	—
Florida, U of	7	55	6	9	39	12	0
Fordham U	3	9	3	3	—	—	—
Fort Lewis C	6	4	—	—	—	—	—
Franklin and Marshall C	18	10	—	—	—	—	—
Furman U	10	16	5	—	—	—	—
Geneva C	1	6	—	—	—	—	—
George Mason U	12	4	—	—	—	—	—
George Washington U	12	10	2	4	—	—	—
Georgetown U	15	0	5	9	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Georgia Institute of Tech	25	0	4	14	a		
Georgia State U	7	2	3	—	—	—	—
Georgia, U of	2	46	10	13	—	—	—
Gettysburg C	6	7	—	—	—	—	—
Glassboro State C	11	0	—	—	—	—	—
Gonzaga U	0	7	—	—	—	—	—
Goucher C	3	13	—	—	—	—	—
Grand Valley State C	0	14	—	—	—	—	—
Grinnell C	3	16	—	—	—	—	—
Gustavus Adolphus C	5	12	—	—	—	—	—
Hamilton C	0	9	—	—	—	—	—
Hamline U	7	7	—	—	—	—	—
Hampden-Sydney C	5	7	—	—	—	—	—
Hampton Institute	4	4	—	—	—	—	—
Hartford, U of	1	4	0	—	—	—	—
Hartwick C	1	2	—	—	—	—	—
Harvard U	0	24	21	26	—	—	—
Harvey Mudd C	17	0	—	—	—	—	—
Haverford C	4	8	—	—	—	—	—
Hawaii, U of	19	5	3	6	—	—	—
Hiram C	7	7	—	—	—	—	—
Hobart and William Smith C	1	5	—	—	—	—	—
Hofstra U	9	1	—	—	—	—	—
Hollins C	0	1	—	—	—	—	—
Holy Cross, C of the	24	13	3	—	—	—	—
Hope C	13	16	—	—	—	—	—
Houston, U of	18	0	4	9	47	24	4
Howard U	2	33	6	3	15	—	—
Humboldt State U	4	6	—	—	—	—	—
Idaho State U	6	1	0	—	—	—	—
Idaho, U of	3	3	3	2	a		
Illinois Benedictine C	17	0	—	—	—	—	—
Illinois Institute of Tech	4	0	14	1	a		
Illinois State U	32	0	6	—	—	—	—
Illinois, U of							
Chicago	17	24	15	14	a		
Urbana-Champaign	54	77	23	60	95	20	11
Illinois Wesleyan U	1	5	—	—	—	—	—
Indiana State U	5	1	2	—	—	—	—
Indiana U	37	97	4	24	—	—	—
Indiana U South Bend	2	7	—	—	—	—	—
Indiana U of Pennsylvania	15	2	5	—	—	—	—
Indiana U-Purdue U							
Fort Wayne	4	1	—	—	—	—	—
Indianapolis	1	28	4	—	—	—	—
Iowa State U	7	3	6	22	72	15	3
Iowa, U of	13	0	5	19	20	3	1
Ithaca C	5	1	—	—	—	—	—
Jackson State U	4	6	1	—	—	—	—
James Madison U	5	10	—	—	—	—	—
John Carroll U	8	14	1	—	—	—	—
Johns Hopkins U	12	0	7	7	—	—	—
Juniata C	6	15	—	—	—	—	—
Kalamazoo C	3	19	—	—	—	—	—
Kansas State U	1	8	4	9	31	6	2
Kansas, U of	2	17	0	7	a		
Kean C of New Jersey[c]					—	—	—
Kearney State C	1	8	—	—	—	—	—
Kent State U	7	10	1	9	—	—	—
Kentucky, U of	4	10	5	3	42	5	0
Kenyon C	11	6	—	—	—	—	—
King's C	10	0	—	—	—	—	—
Knox C	1	25	—	—	—	—	—
Lafayette C	6	14	—	—	32	—	—
Lake Forest C	0	4	—	—	—	—	—
Lamar U	9	7	2	—	42	9	0
La Salle C	6	0	—	—	—	—	—
Lawrence U[d]	3	5	18	2	—	—	—
Lebanon Valley C	7	2	—	—	—	—	—
Lehigh U	24	0	13	5	99	20	1
LeMoyne C	17	0	—	—	—	—	—
Lincoln U	0	4	—	—	—	—	—
Long Island U							
Brooklyn Center	2	10	2	—	—	—	—
C. W. Post C	4	1	—	—	—	—	—
Loras C	4	1	—	—	—	—	—
Louisiana State U							
Baton Rouge	11	0	3	9	75	11	4
Shreveport	3	0	—	—	—	—	—
Louisiana Tech U	1	1	0	—	a		
Louisville, U of	6	13	2	1	—	19	1
Lowell, U of	11	2	5	3	42	3	—
Loyola C	7	5	—	—	—	—	—
Loyola Marymount U	3	0	—	—	—	—	—
Loyola U in New Orleans	0	0	—	—	—	—	—
Loyola U of Chicago	6	19	6	4	—	—	—
Luther C	2	8	—	—	—	—	—
Macalester C	4	9	—	—	—	—	—
MacMurray C	0	4	—	—	—	—	—
Maine, U of	1	3	0	0	43	1	1
Manhattan C[e]	10	4	—	—	67	44	—
Manhattanville C	3	0	—	—	—	—	—
Mankato State U	7	4	1	—	—	—	—
Marietta C	6	1	—	—	—	—	—
Marist C	0	6	—	—	—	—	—
Marquette U	11	4	10	8	—	—	—
Marshall U	6	13	7	—	—	—	—
Maryland, U of	21	85	9	22	a		
Maryland Baltimore County, U of	3	8	2	0	—	—	—
Massachusetts Institute of Tech	38	0	7	36	102	56	18
Massachusetts, U of	20	11	10	15	55	8	4
McMurry C	0	3	—	—	—	—	—
McNeese State U	3	0	2	—	—	—	—
Memphis State U	1	5	0	0	—	—	—
Mercer U	0	5	—	—	—	—	—
Merrimack C	10	0	—	—	—	—	—
Metropolitan State C	17	3	—	—	—	—	—
Miami U	14	56	9	5	—	—	—
Miami, U of	3	65	3	2	—	—	—
Michigan State U	14	11	14	36	66	8	1
Michigan Technological U	22	0	3	3	116	3	—
Michigan, U of							
Ann Arbor	44	0	29	14	a		
Dearborn	13	2	—	—	—	—	—
Flint	4	7	—	—	—	—	—
Middle Tennessee State U	3	21	3	—	—	—	—
Middlebury C	0	5	0	—	—	—	—
Midwestern State U	1	7	—	—	—	—	—
Millersville State C	6	9	—	—	—	—	—
Millsaps C	2	15	—	—	—	—	—
Minnesota, U of							
Minneapolis	28	0	5	19	185	15	17
Duluth	13	13	1	—	—	—	—
Mississippi C	1	11	—	—	—	—	—
Mississippi State U	3	4	1	2	37	4	0
Mississippi, U of	1	34	1	3	20	3	0
Missouri, U of							
Columbia	9	12	5	6	74	8	1
Kansas City	10	18	6	4	—	—	—
Rolla	10	0	3	5	86	12	1
St. Louis	18	8	13	3	—	—	—
Missouri Western State C[c]					—	—	—
Monmouth C	1	7	—	—	—	—	—
Montana C of Mineral Science & Tech	0	3	1	—	—	—	—
Montana State U	8	5	5	5	52	8	1
Montana, U of	0	5	1	1	—	—	—
Montclair State C	5	22	4	—	—	—	—
Moorhead State U	0	1	—	—	—	—	—
Moravian C	6	4	—	—	—	—	—
Morehouse C[f]	1	2	11	0	—	—	—
Morgan State U	7	8	—	—	—	—	—
Mount Holyoke C	0	8	3	0	—	—	—
Mount Saint Vincent, C of[e]	1	1	—	—	—	—	—
Muhlenberg C	3	25	—	—	—	—	—
Murray State U	5	17	6	—	—	—	—
Muskingum C	4	8	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Nebraska, U of							
Lincoln	6	11	3	14	28	1	0
Omaha	5	3	—	—	—	—	—
Nebraska Wesleyan U	0	8	—	—	—	—	—
Nevada, U of							
Las Vegas	0	9	—	—	—	—	—
Reno	1	5	3	2	—	—	—
New Hampshire, U of	14	5	4	4	a		
New Jersey Institute of Tech[b]	—	—	—	—	96	20	3
New Mexico Highlands U	0	0	4	—	—	—	—
New Mexico Institute of Mining & Tech	6	0	3	—	—	—	—
New Mexico State U	1	10	1	1	26	9	—
New Mexico, U of	15	0	8	6	26	6	3
New Orleans, U of	1	11	2	5	—	—	—
New York U	3	35	12	9	—	—	—
Niagara U	1	10	—	—	—	—	—
North Alabama, U of	5	19	—	—	—	—	—
North Carolina A&T State U	5	0	5	—	—	—	—
North Carolina Central U	1	5	1	—	—	—	—
North Carolina State U	18	3	13	4	74	6	4
North Carolina, U of							
Asheville	3	2	—	—	—	—	—
Chapel Hill	37	99	12	26	—	—	—
Charlotte	1	11	3	—	—	—	—
Greensboro	7	4	3	—	—	—	—
Wilmington	7	5	—	—	—	—	—
North Dakota State U	2	15	6	3	—	—	—
North Dakota, U of	0	8	2	4	16	4	—
North Texas State U	4	3	8	7	—	—	—
Northeast Louisiana U	2	0	3	—	—	—	—
Northeastern U	11	0	11	6	a		
Northern Arizona U	5	43	1	—	—	—	—
Northern Colorado, U of	1	7	1	—	—	—	—
Northern Illinois U	13	9	7	2	—	—	—
Northern Iowa, U of	2	12	0	—	—	—	—
Northern Michigan U	1	4	1	—	—	—	—
Northwest Missouri State U	3	4	—	—	—	—	—
Northwestern State U of Louisiana	0	2	1	—	—	—	—
Northwestern U	17	11	25	28	65	17	8
Norwich U	2	1	—	—	—	—	—
Notre Dame, U of	11	11	6	7	53	11	3
Oakland U	9	6	0	—	—	—	—
Oberlin C	3	15	—	—	—	—	—
Occidental C	1	11	—	—	—	—	—
Ohio Northern U	4	9	—	—	—	—	—
Ohio State U	26	0	28	28	66	16	2
Ohio U	9	6	5	6	16	12	0
Ohio Wesleyan U	2	8	—	—	—	—	—
Oklahoma State U	8	9	2	4	45	14	3
Oklahoma, U of	6	20	4	3	49	15	3
Old Dominion U	9	10	8	—	—	—	—
Oregon State U	8	0	5	4	52	17	1
Oregon, U of	7	20	5	9	—	—	—
Pace U	2	3	—	—	—	—	—
Pacific Lutheran U	0	11	—	—	—	—	—
Pacific, U of the	0	16	3	3	—	—	—
Pennsylvania State U	14	15	8	25	160	15	5
Pennsylvania, U of	8	26	5	25	47	18	7
Philadelphia C of Pharmacy & Science	7	0	2	1	—	—	—
Philadelphia C of Textiles & Science	6	0	—	—	—	—	—
Pittsburg State U	2	5	2	—	—	—	—
Pittsburgh, U of	60	44	9	14	72	15	3
Polytechnic Institute of New York	6	0	9	7	48	9	1
Pomona C	9	4	—	—	—	—	—
Portland State U	0	12	2	1	—	—	—
Pratt Institute[b]	—	—	—	—	9	—	—
Princeton U	11	6	11	21	35	8	12
Providence C	2	5	1	0	—	—	—
Puerto Rico, U of							
Mayaguez	19	24	4	—	73	2	—
Rio Piedras	22	16	5	6	—	—	—
Puget Sound, U of	6	1	2	—	—	—	—
Purdue U	19	16	22	33	122	21	11
Purdue U Calumet	1	0	—	—	—	—	—
Randolph-Macon Woman's C	5	4	—	—	—	—	—
Redlands, U of	0	2	—	—	—	—	—
Reed C	14	4	—	—	—	—	—
Regis C	2	1	—	—	—	—	—
Rensselaer Polytechnic Institute	33	0	17	13	92	12	1
Rhode Island, U of	6	1	4	3	17	1	1
Rice U	5	5	2	11	39	9	1
Richmond, U of	1	12	0	—	—	—	—
Rider C	3	0	—	—	—	—	—
Ripon C	5	1	—	—	—	—	—
Roanoke C	4	4	—	—	—	—	—
Rochester Institute of Tech	6	7	6	—	—	—	—
Rochester, U of	13	9	18	13	45	9	0
Rollins C	0	0	—	—	—	—	—
Roosevelt U	2	0	3	—	—	—	—
Rose-Hulman Institute of Tech	8	0	—	—	a		
Russell Sage C	12	0	—	—	—	—	—
Rutgers U							
New Brunswick	73	12	9	9	77	7	3
Newark C of Arts & Sciences	18	5	8	6	—	—	—
Saginaw Valley State C	4	3	—	—	—	—	—
St. Anselm's C	1	8	—	—	—	—	—
St. Cloud State U	2	6	—	—	—	—	—
St. John Fisher C	7	2	—	—	—	—	—
St. John's U	9	0	8	—	—	—	—
St. Joseph C	0	1	3	—	—	—	—
St. Joseph's U	10	11	12	—	—	—	—
St. Lawrence U	9	21	—	—	—	—	—
St. Louis U	8	51	6	—	—	—	—
St. Mary's C	2	2	—	—	—	—	—
St. Olaf C	2	47	—	—	—	—	—
St. Peter's C	1	2	—	—	—	—	—
St. Thomas, C of	2	8	—	—	—	—	—
Sam Houston State U	13	1	2	—	—	—	—
San Diego State U	10	2	19	3	—	—	—
San Francisco State U	10	16	5	—	—	—	—
San Francisco, U of	3	2	—	—	—	—	—
San Jose State U	20	12	16	—	11	6	—
Santa Clara, U of	7	7	—	—	—	—	—
Scranton, U of	8	18	12	—	—	—	—
Seattle U	4	3	—	—	—	—	—
Seton Hall U	10	1	13	3	—	—	—
Shippensburg State C	8	8	1	—	—	—	—
Siena C	4	0	—	—	—	—	—
Simmons C	1	2	—	—	—	—	—
Skidmore C	0	18	—	—	—	—	—
Slippery Rock State C	0	0	—	—	—	—	—
Smith C	8	1	0	0	—	—	—
Sonoma State U	1	9	—	—	—	—	—
South Carolina, U of	2	19	11	13	29	5	0
South Dakota School of Mines & Tech	17	2	0	—	41	0	—
South Dakota State U	0	23	6	—	—	—	—
South Dakota, U of	3	12	3	—	—	—	—
South Florida, U of	17	59	1	5	a		
Southeast Missouri State U	2	11	2	—	—	—	—
Southeastern Massachusetts U	3	14	1	—	—	—	—
Southern California, U of	14	6	2	10	a		
Southern Illinois U							
Carbondale	10	12	3	6	—	—	—
Edwardsville	2	17	5	—	—	—	—
Southern Methodist U	6	16	1	—	—	—	—
Southern Mississippi, U of	1	10	2	6	—	—	—
Southern Oregon State C	3	3	—	—	—	—	—
Southern University & A&M C	4	0	3	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's, certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Southwest Missouri State U	3	20	—	—	—	—	—
Southwest State U	3	7	—	—	—	—	—
Southwest Texas State U	8	1	3	—	—	—	—
Southwestern at Memphis	8	3	—	—	—	—	—
Southwestern Louisiana, U of	0	9	2	—	21	2	—
Southwestern Oklahoma State U	10	4	—	—	—	—	—
Stanford U	28	9	6	20	34	24	7
State U of New York							
Albany	22	3	4	1	—	—	—
Binghamton	5	22	3	4	—	—	—
Buffalo	14	5	3	17	93	21	2
Stony Brook	33	31	2	7	—	—	—
C at Brockport	5	7	—	—	—	—	—
C at Buffalo	10	11	3	—	—	—	—
C at Cortland	3	6	—	—	—	—	—
C at Fredonia	11	10	0	—	—	—	—
C at Geneseo	4	0	1	—	—	—	—
C at New Paltz	11	0	1	—	—	—	—
C at Oneonta	2	20	0	—	—	—	—
C at Oswego	18	0	3	—	—	—	—
C at Plattsburgh	10	11	2	—	—	—	—
C at Potsdam	8	10	1	—	—	—	—
Stephen F. Austin State U	1	15	1	—	—	—	—
Stetson U	1	7	—	—	—	—	—
Stevens Institute of Tech	10	0	13	2	—	—	—
Suffolk U	1	5	—	—	—	—	—
Susquehanna U	4	1	—	—	—	—	—
Swarthmore C	5	6	—	—	—	—	—
Syracuse U	16	7	3	1	27	13	5
Temple U	4	11	6	1	—	—	—
Tennessee Tech U	2	15	1	—	34	7	—
Tennessee, U of							
Knoxville	2	21	6	5	59	12	4
Chattanooga	9	19	—	—	—	—	—
Martin	3	7	—	—	—	—	—
Texas A&I U	4	1	1	—	a		
Texas A&M U	12	9	11	15	127	11	3
Texas Christian U	5	11	0	1	—	—	—
Texas Southern U	22	0	12	—	—	—	—
Texas Tech U	13	8	7	6	50	13	0
Texas, U of							
Arlington	10	16	8	—	—	—	—
Austin	50	0	12	29	102	22	3
Dallas	7	1	1	—	—	—	—
El Paso	14	1	6	—	—	—	—
Texas Woman's U	0	5	0	0	—	—	—
Thiel C	2	6	—	—	—	—	—
Thomas More C	3	0	—	—	—	—	—
Toledo, U of	0	16	4	0	27	7	—
Towson State U	3	5	—	—	—	—	—
Trenton State C	16	0	—	—	—	—	—
Trinity C	11	10	0	—	—	—	—
Trinity U	1	5	1	—	—	—	—
Tri-State U[b]	—	—	—	—	a		
Tufts U	0	25	1	3	32	3	0
Tulane U of Louisiana	0	10	1	0	26	3	0
Tulsa, U of	0	0	—	—	22	10	2
Tuskegee Institute	0	3	2	—	—	—	—
Union C	3	15	0	—	—	—	—
U.S. Air Force Academy	3	6	—	—	—	—	—
U.S. Naval Academy	30	0	—	—	—	—	—
Ursinus C	10	12	—	—	—	—	—
Utah State U	4	0	6	0	—	—	—
Utah, U of	2	22	3	13	36	2	5
Valparaiso U	2	40	—	—	—	—	—
Vanderbilt U	2	22	2	2	a		
Vassar C	1	4	0	—	—	—	—
Vermont, U of	18	0	0	5	—	—	—
Villanova U	10	0	5	3	29	6	—
Virginia Commonwealth U	7	24	1	3	—	—	—
Virginia Military Institute	11	0	—	—	—	—	—
Virginia Polytechnic Institute & State U	6	10	6	12	90	7	1
Virginia, U of	11	72	8	12	35	17	2
Wabash C	15	0	—	—	—	—	—
Wagner C	5	9	—	—	—	—	—
Wake Forest U	7	17	1	0	—	—	—
Washburn U of Topeka	4	5	—	—	—	—	—
Washington C	4	0	—	—	—	—	—
Washington and Jefferson C	2	22	—	—	—	—	—
Washington and Lee U	2	11	—	—	—	—	—
Washington State U	5	12	4	7	26	4	0
Washington U	2	25	10	8	56	15	7
Washington, U of	46	19	13	15	76	16	3
Wayne State U	21	22	4	12	38	20	3
Waynesburg C	6	3	—	—	—	—	—
Weber State C	6	3	—	—	—	—	—
Wellesley C	0	16	—	—	—	—	—
Wesleyan U	9	9	2	0	—	—	—
West Chester State C	9	12	3	—	—	—	—
West Florida, U of	10	0	—	—	—	—	—
West Texas State U	1	20	2	—	—	—	—
West Virginia Institute of Tech	4	0	—	—	12	0	—
West Virginia State C	4	7	—	—	—	—	—
West Virginia U	12	39	8	7	31	4	3
Western Illinois U	5	10	4	—	—	—	—
Western Kentucky U	2	14	5	—	—	—	—
Western Maryland C	1	4	—	—	—	—	—
Western Michigan U	7	15	1	2	—	—	—
Western New England C	2	1	—	—	—	—	—
Western Washington U	15	23	1	—	—	—	—
Westminster C	0	5	—	—	—	—	—
Wheaton C (Illinois)	2	12	—	—	—	—	—
Wheaton C (Massachusetts)	2	6	—	—	—	—	—
Wheeling C	1	0	—	—	—	—	—
Whitman C	4	8	—	—	—	—	—
Whittier C	1	4	—	—	—	—	—
Wichita State U	9	5	2	1	—	—	—
Widener C	2	0	—	—	—	—	—
Wilkes C	4	0	—	—	—	—	—
Willamette U	1	4	—	—	—	—	—
William Paterson C of New Jersey	3	0	—	—	—	—	—
William and Mary, C of	36	5	6	—	—	—	—
Williams C	2	35	—	—	—	—	—
Wisconsin, U of							
Eau Claire	4	9	—	—	—	—	—
Green Bay	2	4	—	—	—	—	—
La Crosse	3	17	—	—	—	—	—
Madison	9	20	13	50	99	15	15
Milwaukee	2	20	3	4	—	—	—
Oshkosh	5	6	0	—	—	—	—
Parkside	2	6	—	—	—	—	—
Platteville	0	4	—	—	—	—	—
River Falls	3	8	—	—	—	—	—
Stevens Point	6	5	—	—	—	—	—
Superior	1	4	—	—	—	—	—
Wittenberg U	0	8	—	—	—	—	—
Wooster, C of	8	25	—	—	—	—	—
Worcester Polytechnic Institute	4	5	2	1	53	10	0
Wright State U	20	14	15	—	—	—	—
Wyoming, U of	2	3	1	4	18	5	0
Xavier U	6	8	3	—	—	—	—
Xavier U of Louisiana	4	25	—	—	—	—	—
Yale U	16	2	24	16	—	—	—
Youngstown State U	6	28	2	—	38	—	—
TOTALS	**4179**	**5687**	**1645**	**1683**	**5963**	**1171**	**293**

a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Added in 1982. d Master's and Ph.D. degrees given by the Institute of Paper Chemistry. e The chemistry programs at Mount Saint Vincent College and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. f Master's degrees given by Atlanta University. **Note:** For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column.

APRIL 25, 1983

CHEMICAL & ENGINEERING

NEWS

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The electronics revolution
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CHEMICAL & ENGINEERING
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APRIL 25, 1983

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- **Frank Press settles into his job as president of NAS.** **Page 5**
- **U.K. starts down the path to lead-free gasoline, following report of lead in the environment.** **Page 5**
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Chemical Companies Tighten Up Cash Management

C&EN survey shows that in 1982, cash stores rose as inventories, receivables, and short-term debt all decreased sharply

David Webber, C&EN New York

Most of the attention paid to the much-ballyhooed reduction of inventories in the chemical industry in 1982 has focused on its potential impact on capacity utilization this year. But the cutback, which paves the way for renewed production when demand picks up, has had a more immediate impact on the balance sheet. There, the inventory trimming capped a two-year trend toward tighter management of day-to-day cash flow that has included sharp reductions in accounts receivable and short-term debt.

Industry customarily attempts to improve its liquidity (cash and relative cash coverage of liabilities) during recessions. To do so, it must plug the biggest short-term cash drains—inventories and receivables. If it can, it reduces its financing requirements, and short-term debt tends to decline. Total cash and marketable securities (short-term investments and the like) increase.

On average, chemical companies achieved these goals last year. A C&EN survey of the annual reports of 20 U.S. companies with a large share of the industry's basic chemicals production shows a 6% rise in cash and marketables in 1982 after an equal rise the year before. This compares with a drop in 1980, the previous recession year (when companies had a more difficult time believing they were actually in a recession), and a 12% increase in 1975.

Still, the increase in cash was accompanied by only a slight improvement in liquidity. The broadest measure of a company's cash coverage of its liabilities, the current ratio (current assets divided by current liabilities) actually fell on average

Cash on hand and cash ratios rose last year

	1982 (recession)			1981			1975 (recession)			1974		
	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio
Air Products[a]	$ 64.3	1.2	0.14	$ 95.9	1.3	0.22	$ 37.2	1.3	0.19	$ 45.8	1.4	0.28
Allied	176.0	1.3	0.15	181.0	1.5	0.13	86.0	2.2	0.27	72.8	2.0	0.22
American Cyanamid	319.8	2.0	0.42	215.2	1.9	0.26	154.1	2.4	0.46	179.4	2.4	0.53
Celanese	104.0	1.9	0.20	235.0	2.0	0.40	146.0	1.7	0.36	117.0	1.7	0.31
Diamond Shamrock	82.6	1.7	0.17	66.2	2.0	0.14	52.7	2.1	0.28	35.5	1.4	0.16
Dow Chemical	183.0	1.8	0.08	93.0	1.7	0.04	374.9	1.5	0.25	423.3	1.4	0.27
Ethyl	94.0	2.3	0.45	121.0	2.2	0.52	103.9	3.5	0.99	42.5	2.6	0.34
W. R. Grace	164.5	1.7	0.17	84.1	1.6	0.07	110.1	1.8	0.16	168.2	1.6	0.20
Hercules	34.2	2.2	0.10	27.5	2.6	0.08	28.4	2.0	0.12	22.2	2.0	0.08
Lubrizol	25.4	2.7	0.22	49.6	2.6	0.39	44.9	3.0	0.70	37.6	2.4	0.48
Monsanto	414.0	2.6	0.44	426.0	2.4	0.40	425.6	3.4	0.88	324.1	2.9	0.63
National Distillers	141.1	3.5	0.60	136.7	4.0	0.65	105.6	3.8	0.65	106.5	3.5	0.59
Olin	77.1	1.8	0.20	35.8	1.8	0.10	98.2	2.4	0.44	96.2	2.3	0.46
Pennwalt	14.7	1.9	0.08	9.1	2.2	0.05	21.9	3.1	0.22	2.2	2.0	0.01
PPG Industries	84.2	1.9	0.14	103.7	2.3	0.22	163.8	2.6	0.57	84.8	2.3	0.29
Reichhold Chemicals	15.2	2.7	0.22	6.4	2.5	0.07	5.6	2.2	0.11	22.8	2.3	0.45
Rohm & Haas	113.8	2.9	0.45	50.9	2.6	0.18	17.5	2.4	0.09	19.7	2.3	0.10
Stauffer Chemical	148.7	2.5	0.45	62.2	2.5	0.21	52.9	3.1	0.42	53.5	2.5	0.39
Union Carbide	154.0	2.0	0.09	253.0	2.2	0.15	585.1	2.5	0.55	426.1	2.2	0.38
Witco Chemical	49.0	2.2	0.32	68.2	1.8	0.31	14.5	2.4	0.26	14.6	1.9	0.19
TOTAL (average for ratios)	**$2459.6**	**2.1**	**0.26**	**$2320.5**	**2.2**	**0.23**	**$2628.9**	**2.5**	**0.40**	**$2296.8**	**2.2**	**0.32**
ANNUAL CHANGE	**6%**			**6%**			**15%**			**−11%**		

a Fiscal year ends Sept. 30. **Note:** Current ratio is current assets divided by current liabilities. Cash ratio is cash and marketable securities divided by current liabilities.

Companies trimmed day-to-day financing needs in 1982

$ Millions	Inventories	% change 1982	% change 1981	Receivables	% change 1982	% change 1981	Accounts payable	% change 1982	% change 1981	Short-term debt	% change 1982	% change 1981
Air Products[a]	$ 112.9	13%	21%	$ 303.3	3%	−2%	$ 209.5	11%	4%	$ 82.5	13%	115%
Allied	647.0	−23	40	728.0	−22	19	769.0	−21	45	38.0	−28	61
American Cyanamid	513.5	−4	8	681.4	−14	8	572.9[b]	−6	−1	130.2	−4	73
Celanese	420.0	−5	13	454.0	−3	−9	367.0[b]	−13	6	52.0	−18	29
Diamond Shamrock	348.6	−4	−7	325.2	−31	−7	301.0	1	11	19.1	−14	5
Dow Chemical	1746.0	−17	9	2,034.0	−12	7	1055.0	−21	12	276.0	−44	−33
Ethyl	161.5	10	2	206.7	−10	−6	70.5	−7	−5	18.4	−49	84
W. R. Grace	876.4	−5	12	620.2	−25	10	472.9	−11	7	176.0	−12	−12
Hercules	368.3	−10	21	380.5	−9	0	161.2	7	−2	57.9	−21	−51
Lubrizol	134.1	−6	−1	139.0	−2	−10	72.3	2	−10	0	0	0
Monsanto	824.0	−6	5	1,076.0	0	−20	379.0	−23	16	131.0	−25	−27
National Distillers	412.2	−5	2	243.3	−9	−9	107.6	3	−13	51.2	132	−4
Olin	265.3	−15	8	288.7	5	−6	136.2[b]	−13	6	87.5	181	−56
Pennwalt	141.0	−8	−26	147.4	−10	−24	49.8	−17	−16	38.1	36	−62
PPG Industries	403.5	2	7	570.1	11	−2	483.4[b]	39	−6	89.2	−17	85
Reichhold Chemicals	61.5	−25	11	99.0	−18	−10	41.4	−29	−16	9.9	−21	−22
Rohm & Haas	292.3	−23	18	230.6	−17	3	194.5[b]	−13	86	60.1	8	70
Stauffer Chemical	279.1	−10	1	390.9	18	−9	99.4	−14	−18	113.6	73	−76
Union Carbide	1740.0	−9	1	1,420.0	−6	−5	415.0	−6	2	328.0	51	−32
Witco Chemical	96.9	−17	39	175.7	−12	4	140.9[b]	−20	12	8.3	−37	99
TOTAL	$9944.1	−9%	8%	$10,514.0	−3%	−9%	$6098.5	−10%	−19%	$1767.0	−6%	−24%

[a] Fiscal year ends Sept. 30. [b] Includes accrued liabilities.

among the 20 surveyed firms, from 2.2 in 1981 to 2.1 in 1982. In the 1974–75 period, by contrast, companies clearly approached cash management more rigorously, raising the current ratio from 2.2 to 2.5.

The current ratio does not give a complete picture of the industry's cash management, however, since companies were actively reducing inventories, which are a dubious asset in a liquidity measurement when demand is low. Using a different financial yardstick, the cash ratio (cash plus marketable securities divided by current liabilities), the chemical companies in the survey look better, managing a respectable improvement from 0.23 in 1981 to 0.26 last year. Nonetheless, the cash ratio achieved in this recession compares relatively unfavorably with that of the 1974–75 span, when it rose on average from 0.32 to 0.40.

On the whole, however, analysts say chemical producers weathered the recession in good fashion in financial terms. "I think they managed their cash very well," comments Robert Todd, chemical specialist for Citibank.

Indeed, 11 of the 20 surveyed firms increased their reserves of cash and marketables last year. Most prominent were American Cyanamid, up 49%; Dow Chemical, up 97%; W. R. Grace, up 97%; Rohm & Haas, up 124%; and Stauffer Chemical, up 140%. A few companies had large decreases in cash on hand, notably Celanese, down 40%; and Union Carbide, down 39%. Five companies—American Cyanamid, Diamond Shamrock, National Distillers & Chemicals, Olin, and Pennwalt—increased their cash and marketables stores for the second year in a row.

The overall increase was the result of greatly tightened financial controls. Inventories, which had grown 8% in 1981, declined 9% last year. Seventeen of the 20 surveyed producers cut their inventory levels, led by Reichhold Chemicals, down 25%; and Allied and Rohm & Haas, both down 23%. And although receivables were down only 3%, it was the second consecutive year of decline for eight individual companies and for the overall average.

As a result, the amount of short-term debt (both notes payable and that portion of long-term debt due this year) shrank for the second year in a row. Dow Chemical, still one of the most cash-poor chemical producers (with a cash ratio of 0.08), cut its short-term debt load 44%. Eleven other firms registered mostly sizable decreases as well.

Dow's results, in fact, reveal one of the most concerted efforts at tightening up cash management in the industry. On both sides of the balance sheet, its improvements were far better than the average for the surveyed firms. But Dow, of course, was so low in terms of liquidity—a cash ratio of just 0.04 in 1981, for instance, and short-term debt of $736 million in 1980—that it had the most to do. On average, the 20 companies' liquidity as they come out of the most recent recession is far below where it was in 1975, suggesting the industry may have decided that the average 40% coverage of current liabilities with cash it enjoyed then is not necessary. Indeed, only six firms now have a cash ratio above 0.35, compared to 10 firms in 1975.

And, as the recovery continues, the financial ratios built up at the end of 1982 will begin to erode. Inventories will rise again as companies prepare for demand, and receivables will increase as producers offer better terms to customers as a way to win market share. □

Rubber-Processing Chemicals Recover After 20-Year Low

Stephen C. Stinson
C&EN New York

The highly complex world of organic rubber-processing chemicals—involving dozens of companies in a more than $400 million annual business—has begun a weak recovery in the U.S. this year after hitting a 20-year low in 1982. Production of these chemicals may rise 7% to 132,000 metric tons in 1983, if American auto makers, the prime customers, produce 6 million cars this year, or only 3% to 127,000 metric tons if they do not.

As U.S. economic recovery gets under way, rubber processors and chemical producers are adjusting to a new climate in marketing of organic rubber-processing chemicals. One main influence is a strengthening dollar, which is attracting a rising tide of imports. Another internal matter shaking up the business is withdrawal of American Cyanamid from production of important workhorse accelerator types.

Over the longer term, renewed growth in rubber chemicals may be hampered by downsizing of tires for smaller cars, a trend that will not be complete until about 1990. Observers are divided about what effect this will have. Pessimists predict that downsizing will result in slower growth this decade for rubber chemicals than that of the gross national product. Those who are more optimistic point to the fact that tires will last longer in coming years, because people are not driving so much as they once did. According to this view, such tires will need increased levels of antioxidants and antiozonants to protect them from deterioration just while standing still over the increased number of years that consumers will demand that they last.

Such other long-term trends in the rubber industry as possible elimination of spare tires as original automotive equipment and increased use of natural rubber may not have significant impacts on rubber-processing chemicals. If, as some in the industry think, auto makers succeed in getting buyers to accept cars with no spares in the next three to five years, this will result in a one-time-only impact on rubber chemicals. Tires will keep wearing out naturally, and rubber chemicals sales will resume growing through original equipment and replacement tire sales.

Use of natural rubber in the U.S. got a boost in the 1970s both because of the rise in feedstock prices for synthetic rubber and of the continuing conversion of tires to radial rather than bias-ply construction.

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Rubber-processing chemicals: a definition

The organic rubber-processing chemicals described in this report are the 200-odd organic substances used by rubber compounders in making vulcanized rubber. With the exception of such products as crepe rubber shoe soles and adhesives, raw rubber has no other commercial use. It has to be extensively compounded first with specialized chemicals.

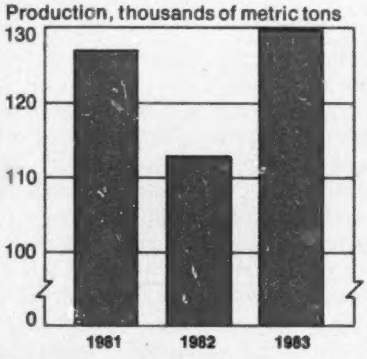
This report covers accelerators to speed the cross-linking reaction with sulfur, activators to potentiate the accelerators (sometimes called secondary accelerators), retarders to delay vulcanization, peptizers for viscosity reduction, antioxidants and antiozonants to protect rubber in processing and in use afterward, and sulfur donors to enhance quality of cross-links. Rubber compounders use an average of 4.5 lb of these chemicals per 100 lb of raw rubber.

Organic chemicals not treated in this report include mercaptans that regulate polymerization of monomer to raw rubber, peroxides that initiate such polymerization, fatty acids added as activators, and the various oils used as extenders, softeners, and physical plasticizers.

Among inorganic substances excluded in this report are elemental sulfur as vulcanizing agent, zinc oxide and other oxide activators, carbon black reinforcements (an important, large volume constituent of finished tires), and other reinforcements and fillers such as alkaline earth carbonates and silicates, silica, and clays.

Because natural rubber latex contains antioxidant substances and fatty acids, processing requires no stabilizers or fatty acid activators. Such subtle differences in natural versus synthetic rubber processing will be difficult to detect, however, amidst the overall boom-and-bust responses of the rubber industry to economic cycles.

Rubber-processing chemicals at a glance



Major classes: Accelerators, activators, and vulcanizing agents 32%; antioxidants and antiozonants 53%

Foreign trade: Exports, 17% of U.S. production. Imports, 3% of U.S. consumption and growing rapidly

Prices: Average $1.60 per lb

Commercial value: $460 million for U.S. production in 1983

Some two dozen domestic producers and a few major U.S. suppliers that import their chemicals all will vie for the approximately $420 million worth of organic rubber-processing chemicals U.S. industry will use this year. If all these sales were made by one firm as its sole business, that firm would rank number 70 on C&EN's roster of top chemical producers. If the 200 or so such chemicals all were expressed as one chemical, its volume would be only one quarter of that needed to make it number 50 on C&EN's list of the Top 50 Chemicals.

Rubber chemical sellers are secretive about their shares of U.S. merchant sales, but observers agree that in the U.S., Monsanto is first, Uniroyal second, and R. T. Vanderbilt third. In the rest of the world, where the market is four times the size of that in the U.S., Monsanto is again the leader, with Bayer and Uniroyal tied for second place. The picture is complicated by the fact that three major rubber companies—B. F. Goodrich, Goodyear, and Uniroyal—produce captively for themselves as well as sell in the merchant market.

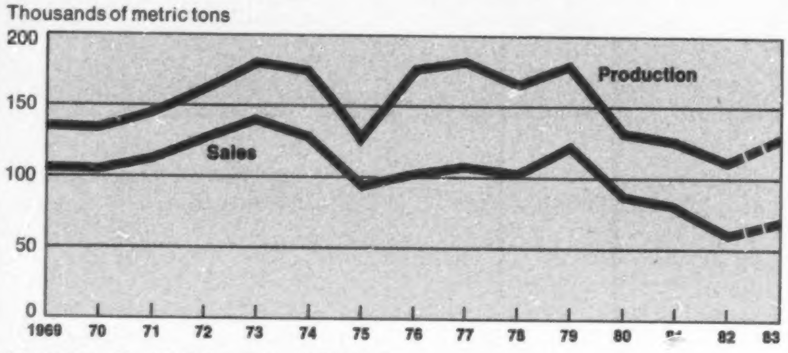
In terms of production, Monsanto may have a 35% share, 1983 sales of 45,000 metric tons worth $160 million. Goodyear's share may be 30%, or 40,000 metric tons valued at $140 million. The company uses almost all of this internally, however. Uniroyal could produce about 15% of U.S. rubber chemicals, which would translate to 20,000 metric tons or $70 million. Uniroyal is very aggressive in the merchant market, and may use only one third of its output in-house for rubber production. Goodrich could come in for as little as 5%, 7000 metric tons worth $25 million. This firm may use half of this volume captively.

Exports of rubber-processing chemicals may come to 22,000 metric tons in 1983, worth almost $80 million. In addition, some U.S. companies serve other areas of the world by maintaining production plants abroad. Predicasts of Cleveland, Ohio, a business information and research firm, estimates that growth in rubber consumption, and therefore of processing chemicals, will be greater in the less industrialized than in more industrialized countries. For example, a Predicasts study predicts worldwide increases of 4% per year, compared with only 1.3% annual growth in North America.

With imports to the U.S., the picture is less clear. Some observers say that the U.S. will import only 5000 metric tons of rubber-processing chemicals in 1983, with a value of $18 million. To others, the amount seems much higher—perhaps 15,000 metric tons and $50 million. There is general agreement that declines in their own markets coupled with the rising value of the dollar have encouraged many foreign companies to move their products more aggressively in the U.S.

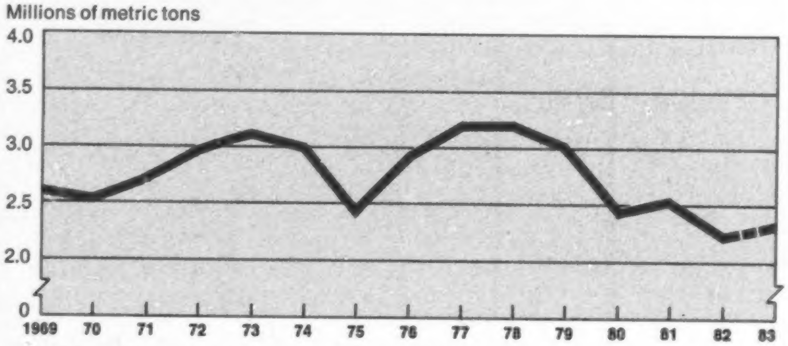
U.S. companies are responding to this new climate of relatively high growth potential in overseas markets, low expected growth in the U.S., intensifying competition everywhere, and the advance of imports into the U.S. Strategies include research on new chemicals, re-emphasis on technical service, production of nondusting grades of chemicals, and investment in foreign production. Perhaps the most drastic move was by American Cyanamid, which stopped making benzothiazole and sulfenamide accelerators in 1982.

Rubber chemicals sales have slumped since 1979 . . .



Sources: International Trade Commission, C&EN estimates

. . . and rubber consumption has been down since 1977



Note: Rubber consumption includes natural rubber. **Sources:** Rubber Manufacturers Association, C&EN estimates

As American Cyanamid marketing manager William Bush explains, the withdrawal from these compounds came from a need to cease production at the company's Bound Brook, N.J., plant. "So many businesses had gone out of production at Bound Brook that fixed costs were being spread over a diminishing base," Bush says. "We also faced a large investment to renovate the plant."

The firm still is committed to serving the rubber industry with specialty chemicals. For example, the company has started U.S. production of an accelerator for neoprene rubber, 3-methyl-2-thiazolidinethione. This compound is of interest because of its potential to replace ethylenethiourea, which has been found carcinogenic in rats and mice. Another recent product from Cyanamid is a peptizer based on dithiobis-(benzanilide) and an activator.

"We will compete by reducing our product line to specialties where we have positions in technology, manufacturing costs, and raw materials that are as good as anyone else's," Bush says. "We will research new products in those areas, especially adhesion promoters, and limit our sales efforts to those areas."

Adhesion promoters enhance adherence of rubber to tire cord and so become increasingly important as radial tires continue replacing bias-ply types. This type of chemical system was one bright spot at Cyanamid and other rubber chemical firms in the overall gloom of 1982. According to the Rubber Manufacturers Association, which has broken out such figures only since 1981, sales of replacement radial tires rose almost 13% from 1981 to 1982, and the number of customers choosing radials as replacement tires grew from 61% to 66%. This more than overcame a drop of 5% in radials as original equipment as new car sales declined. As original equipment, the number of radial tires supplied with new cars remained about 84%.

Some companies have reacted to Cyanamid's withdrawal by starting production of accelerators such as *N*,*N*-diisopropylbenzothiazolesulfenamide, for which Cyanamid was the only U.S. producer. But one other rubber-processing chemicals company, Pennwalt, was caught short by Cyanamid's move. Pennwalt had an agreement with the New Jersey firm in which Cyanamid packaged accelerators under the Pennwalt label at Bound Brook. However, Pennwalt has managed to take Cyanamid's withdrawal in stride, according to John R. Smith, who is marketing manager for Pennwalt's rubber accelerator products department, and even fit the new situation into the overall reorganization of its rubber chemicals effort.

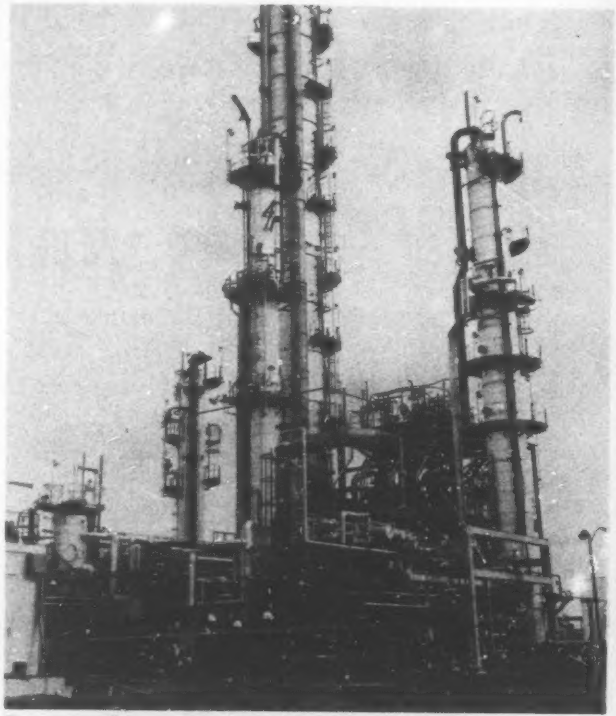
Before 1982, Pennwalt had sold accelerators to the rubber industry through its organic chemical division, as well as peroxide initiators of its Lucidol division in Buffalo, N.Y. Rubber processors use peroxides as vulcanizing agents when needed for maximum heat stability and minimum compression set. Realizing the need to concentrate its rubber chemicals marketing effort in the new climate of the 1980s, Pennwalt's management hired Smith in 1982 to organize the accelerator department in a new office in Hudson, Ohio, near Akron. The company reassigned sales of peroxides for the rubber industry to Lucidol.

The chemicals that Smith sells for Pennwalt in the U.S. will come from Italy. The company has long had a plant in Ticino, Italy, as a joint venture with Industria Chimica del Ticino to make dithiuram disulfides and dithiocarbamates. In mid-1982, the joint venture opened a $15 million, 15,000 ton-per-year plant and research laboratory at Termoli to produce benzothiazoles. The two plants will produce for Pennwalt's needs in the U.S. and the rest of the world. The laboratory will work on new products Pennwalt must have to remain competitive this decade. For now, Smith is working to stock warehouses here with products from Termoli. In the future, he will bring on production of nondusting grades of chemicals. Perhaps his greatest competitive asset, Smith says, is the newness of the company's plants and

1979 was peak year for production of rubber processing chemicals in the U.S.

Thousands of metric tons	1981[a]	1979	% change
Accelerators, activators & vulcanizers	43.2	60.1	−29%
Aldehyde-amine adducts	0.3	0.4	−25
Thiazoles	33.9	49.0	−31
2,2′-Dithiobis(benzothiazole)	5.5	7.5	−27
2-Mercaptobenzothiazole, zinc salt	0.7	0.9	−23
Dithiocarbamates	4.5	4.9	− 8
Dimethyldithiocarbamate, zinc salt	0.8	1.7	−50
Thiurams, xanthates & sulfides	1.1	1.6	−27
Others[b]	3.3	4.8	−32
Antioxidants, antiozonants & stabilizers	67.7	85.9	−21
Amino compounds[c]	41.2	53.7	−23
Phenylenediamines	28.1	28.7	− 2
Phenolics & phosphites	26.5	32.8	−18
Polyphenolics	4.2	6.1	−30
Alkylphenols	2.8	3.2	−13
Styrenated phenols	0.5	0.4	+20
Other phenolics & phosphites	19.0	22.5	−16
Others[d]	14.6	32.4	−55
TOTAL[e]	126.8	178.0	−29%

a Last year for which data are available. b Includes guanidines. c Includes acetone- and aldehyde-amine adducts. d Includes blowing agents, peptizers, lubricants, and polymerization regulators. e Figures do not add to total because of rounding. Source: U.S. International Trade Commission



Precursor for many rubber chemicals is aniline, produced here in USS Chemicals plant at Haverhill, Ohio

processes, which will allow Pennwalt to compete successfully.

The competitive stance that everyone in the rubber industry watches is that of Monsanto, the leading supplier of rubber-processing chemicals to the industry. Says Roger Spiller, who is business director for that business, "Rubber chemicals have been a good business for Monsanto. We are dedicated to maintaining our position.

"We have some interesting research projects, looking for chemicals that will benefit us and the industry. We will continue our heavy emphasis on technical service, which we feel the industry values.

"Consistent with the present tough economic times in the rubber industry, we continue to take a hard look at the investments needed to maintain that position. Monsanto has an emphasis on asset management. We're taking a hard look at the inventories we keep and where we keep them. We will maintain our historic level of service with the minimum possible inventory."

The second leading merchant seller in the U.S., Uniroyal Chemical, presents a picture of a major rubber products company that consumes

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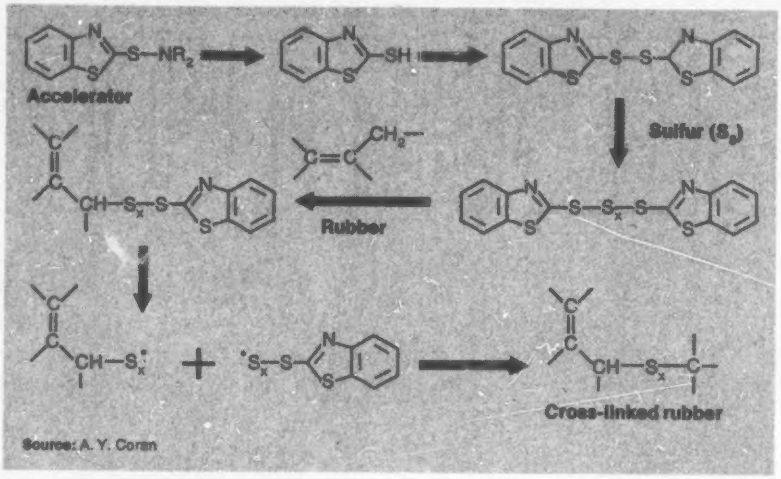
Accelerators catalyze formation of sulfide cross-links



Source: A. Y. Coran

part of its production of processing chemicals captively. Robert Mazaika, who rose through the ranks to become general manager of the rubber chemicals business in 1982, says the company will continue its record of technological innovation and expansion into overseas production. Mazaika points out that Uniroyal pioneered in *N*-alkyl-*N'*-aryl-*p*-phenylenediamine antiozonants, as well as blowing agents based on hydrazine.

Uniroyal recently expanded capacity at its two joint-venture companies, Ameyal in Mexico City and Premier Chemical Co., Taipei, Taiwan. In addition to its U.S. plants in Geismar, La., and Naugatuck, Conn., the company owns Uniroyal do Brasil, with plants at Rio Claro and Maua; Uniroyal Chimica, Latina, Italy; and Uniroyal Ltd. (Canada), which produces at Elmira, Ont., and Clover Bar, Alta.

Explaining his investment strategy abroad, Mazaika says, "We base decisions on patterns of customs duties and stages of development in various countries. Developing countries eventually reach a stage of rubber consumption that demands local production of rubber chemicals. Also, most major rubber companies are located around the world, and it's good for them to be able to choose the same supplier everywhere.

"We service our customers at lowest cost in terms of customs duties. For example, we service customers in the U.K. from our plants in Canada."

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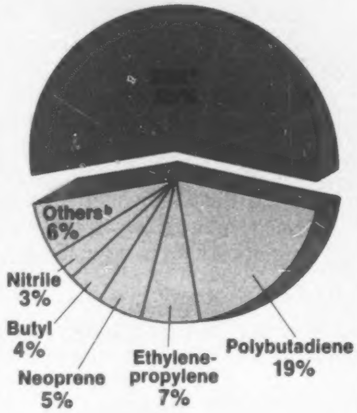
White crumbs of synthetic rubber move along drying tower at Goodyear's plant at Beaumont, Tex.

by Uniroyal are an activated azodicarbonamide blowing agent intended to replace dinitrosopentamethylenetetramine, a *p*-phenylenediamine antiozonant, and a hindered-phenolic antioxidant that is also a metal deactivator. Such metals as copper, which can alternate between different oxidation states, catalyze oxidation of rubber. Metal deactivators chelate these ions and inhibit this catalytic effect. Uniroyal's new compound with a combined effect is *N,N'*-oxamidodi-2-ethyl bis[3-(3,5-di - *tert* - butyl-4-hydroxyphenyl)-propionate].

Two other rubber companies that produce rubber-processing chemicals for captive use and also sell in the merchant market are B. F. Goodrich and Goodyear Tire & Rubber. Both firms produce chemicals for the accelerator and the antioxidant/antiozonant systems of rubber compounding. In agreements that are 60 years old, Goodrich distributes its antioxidants and Goodyear its accel-

SBR leads among synthetic rubbers in volume



Total 1982 consumption = 1,624,800 metric tons

a Styrene-butadiene rubber. b Includes polyisoprene and silicones.
Source: Rubber Manufacturers Association

Glossary of rubber terms

Accelerator. Speeds cross-linking of rubber by sulfur. Example: 2,2'-dithiobis(benzothiazole).

Activator. Renders accelerators more potent. Example: 1,3-diphenylguanidine.

Antioxidant. Protects cured rubber parts against oxidative degradation in service. Antioxidants that protect synthetic rubbers before and during processing are **stabilizers.** Examples: *N*-isopropyl-*N'*-phenyl-*p*-phenylenediamine, which also is an antiozonant, and octylated diphenylamine, which is not.

Antiozonant. Additive that protects rubber parts against ozone. Examples: waxes, which migrate continuously to the surface to form a barrier, and *N,N'*-bis(1,4-dimethylpentyl) -*p*-phenylenediamine, which reacts with ozone and/or products formed by the reaction of rubber with ozone.

Bonding agent. Increases rubber adherence to fabric or fiber. Example: resorcinol plus hexamethylenetetramine.

Cure. Cross-linking of rubber polymer chains to impart elastomeric properties, as by sulfur, peroxides, or quinone oximes. Also called vulcanization.

Cure time. Time needed for rubber compounds to reach maximum viscosity or modulus at a given temperature; the sum of the scorch time and cross-linking time.

Hard rubber. Rubber cured with 15 to 40% of added sulfur.

Latex. Water emulsion of rubber polymer, used as is for coating or dewatered for making solid parts.

Lubricant. Additive that eases flowing in molds or extrusion.

Mastication. Preliminary physical and chemical breakdown, usually of natural rubber, in a mill or mixer to reduce viscosity for further compounding.

Peptizer. Compound that promotes chemical breakdown of rubber during mastication. Also called **plasticizer.** Example: pentachlorothiophenol.

Phr. Parts-per-hundred-rubber; the number of parts by weight of compound added to 100 parts of rubber.

Retarder. Additive that lengthens time before curing. Example: phthalic anhydride. Sulfenamide retarders like *N*-cyclohexylthiophthalimide have acquired the separate name of **prevulcanization inhibitors.**

Reversion. Decrease in viscosity or modulus of rubber from excessive working.

Scorch. Premature curing.

Scorch time. Safety margin of time that rubber compound can be worked at a given temperature before curing begins.

Soft rubber. Rubber cured with 0.5 to 8% of sulfur.

Stabilizer. Antioxidant that protects synthetic rubber from oxygen, heat, and light degradation, from newly polymerized latex through fabrication. Example: tris(nonylphenyl) phosphite.

Sulfur donor. Organic polysulfide that replaces some sulfur in rubber compounds and promotes curing mostly by monosulfide cross-links in a process called **efficient vulcanization.** Example: tetramethylthiuram disulfide.

Vulcanizing agent. Substance that cures rubber by forming cross-links between polymer chains. Examples: sulfur, sulfur donors, peroxides, quinone derivatives, and phenolic resins.

CIRCLE 8 ON READER SERVICE CARD →

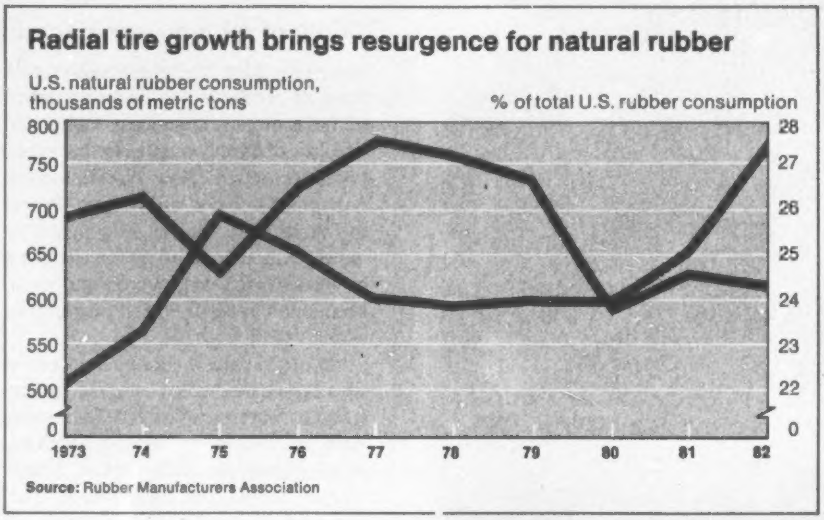
erator-related products through R. T. Vanderbilt Co., Norwalk, Conn. In turn, Goodrich sells it accelerators and Goodyear its antioxidants through their own sales forces.

John E. Stroope, general manager for Goodrich's rubber chemicals, is one of those who have felt the ripple of American Cyanamid's shutdown of accelerator production. Of his own firm's plans, he says, "We do plan to compete. We have no plans to withdraw. People asked us that after American Cyanamid's move."

Goodrich does not produce rubber chemicals outside the U.S., but sells products of its U.S. plants in Akron and in Henry, Ill., overseas. "We want a role in the international market," says Stroope. "I think rubber chemical exports have held up throughout the industry generally, because companies view the international market as important and are willing to accept problems of recession here and of currencies in other countries. You can see from other companies' production overseas how importantly they view it."

Meanwhile, Goodyear is responding to the new rubber chemicals selling climate by involving its research people more in marketing. Joel Muse Jr., for example, who is Goodyear's manager of organic chemicals research and development, will work more closely with the sales side in the future. Development of new products and modernization of its plants also will figure greatly in improving the company's competitive stance.

"We will be more aggressive in the marketplace," says Muse. "Our applications R&D people are going to be out there more in the near future. We're reorganizing our effort. In the past, we had two applications groups, one for rubber chemicals and another for rubber. We're going to combine these into one applications group. Part of that group will be out in the field a great deal of the time, making calls with the salesmen. The other part will be back doing the needed work to get our products to work and to introduce new products."


Radial tire growth brings resurgence for natural rubber

Source: Rubber Manufacturers Association

One recent product from Goodyear is an antioxidant that Muse describes as a *para*-oriented styrenated diphenylamine. Though he will continue research on new chemical types, Muse says that the next advances may come through new formulations. "We're looking for cheaper antioxidants," Muse says. "There is a lot of interest in antioxidants that are synergistic with others, so you use less compound. We're also interested in polymer-bound antioxidants, and we have a promising prospect in that area."

Goodyear recently announced that it is spending $15 million to modernize plants in Bayport, Beaumont, and Houston. Some of that will go toward improving production and processes for rubber chemicals. In the future, the company will appropriate more money to extend the modernization of its other domestic plants.

Tapper cuts rubber tree in Sumatra for creamy latex used in radial tires

In addition to distributing rubber-processing chemicals produced by Goodrich, Goodyear, and many other companies, domestic and foreign, Vanderbilt produces for itself at Bethel, Conn., and Murray, Ky. Sales manager Donald Gorman says the company will rely on new products and a recently formed joint venture in Mexico to compete in the 1980s. But most important will be its current high quality of service. Gorman points to the 16 warehouses the company has in the U.S. and Canada, more than any other firm. He says that Vanderbilt's sales force are industry veterans, having come from such posts as technical director at other companies. Thus they can double as technical service and sales representatives. Vanderbilt also publishes extensively on rubber compounding. Its handbook, a 1000-page tome with formulating information about dry rubber goods, was last put out in 1978. The next edition will appear in 1988. Vanderbilt is also at work on a similar book on latex rubber compounding for 1984. The most recent edition came out in 1954.

Vanderbilt's joint venture with Artivi of Mexico City is only six months old, so the company has not yet benefited from production there. Gorman expects the arrangement to

CIRCLE 8 ON READER SERVICE CARD

Innovations in finished rubber include this spraying technique by Goodyear, used here on fuel cells

Origin of rubber goes back to the Aztecs

Before reaching its sophisticated current level of compounding using a host of complex organic chemicals, rubber had a history of development going back four centuries. A true New World product, natural rubber first showed up among the Aztecs in Mexico. The synthetic variety was pioneered by the Germans in World War I and levered into mass production in the U.S. and Germany in World War II.

1521: Spanish conquistadors in Mexico see the Aztecs using a gum from trees to waterproof utensils and make balls for games. Europeans adopt the South American Indian word "caoutchouc" for the gum, derived from "caa" (tears) and "ochu" (wood).

1770: Joseph Priestley writes to a friend that a piece of the gum makes a good "rubber" to erase pencil marks, but he is probably not the first person to use the word.

1819: Manufacture of rubber articles begins in England; products eventually include waterproof shoes and the raincoat invented by Charles Macintosh. But rubber goods are still inferior, becoming sticky in summer and brittle in winter.

1839: Charles Goodyear accidentally discovers that a compound of rubber, sulfur, and lead carbonate cures to a hard, resilient, infusible solid on heating. Thomas Hancock discovers the process independently and coins the term "vulcanization." Goodyear gets a patent, U.S. 3633, June 15, 1844.

1876: British entrepreneurs bring 70,000 seeds of the rubber tree, *Hevea brasiliensis*, to England from Brazil, which previously has had a monopoly on world rubber production. The British send 3000 seedlings, grown in Kew Gardens, London, to start plantations in Ceylon and Malaya. By 1900, plantings reach 4000 acres in these two countries.

1906: George Oensager at Diamond Rubber Co., Akron, discovers that aniline accelerates vulcanization. This compound becomes the first in a long line of organic accelerators to be commercialized in coming decades.

1910: Recent invention of the automobile stimulates production of 94,000 tons per year of natural rubber as prices skyrocket to $3.12 per lb. Chemistry professor Carl Dietrich Harries of the University of Kiel, Germany, discovers that sodium catalyzes polymerization of 2,3-dimethylbutadiene to a synthetic "methyl rubber."

1918: By the end of World War I, Germany has produced a total of 2350 tons of methyl rubber.

1927: German chemists begin development of Buna S (butadien-natrium-styren) rubber, spearheaded by work of chemistry professor Karl Ziegler at the University of Heidelberg. The first German patents begin appearing on rubbers made by reactions of di- and trichloroalkanes with alkali polysulfides.

1931: Du Pont announces neoprene, a synthetic rubber made from 2-chloro-1,3-butadiene (chloroprene), whose commercial synthesis was developed by Wallace H. Carothers.

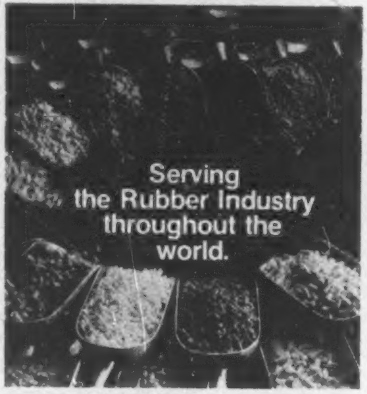
1942: Cut off from imports of natural rubber during World War II, the U.S. government orders planting of 75,000 acres of the guayule shrub. After the war, efforts on guayule rubber will be abandoned. U.S. industry gears up to produce various synthetic rubbers, which will amount to 700,000 tons per year in 1945.

1955: Studies of tire cracking in the smog-laden atmosphere of Los Angeles implicate ozone as the cause, leading to use of antiozonants in rubber formulations.

1983: World rubber production is 12 million tons per year, of which only 30% is natural rubber. The U.S. consumes 2.5 million tons this year, 25% of it natural.

assist marketing efforts in Latin America. On the new products front, Vanderbilt recently introduced the zinc salt of 2-mercaptotoluimidazole, an antioxidant that is synergistic with others.

Among U.S. rubber-processing chemical producers, Mobay Chemical Corp., Pittsburgh, has not yet reached the commanding position in this country that its parent, Bayer of Leverkusen, West Germany, enjoys worldwide. Concerning Mobay's plans to compete here in the 1980s, product manager Al Rizzer says, "Our advantage is that we have the broadest product line of anyone. We can put together the broadest pack-



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ACS Rubber Division is largely independent organization

The American Chemical Society's Rubber Division is a dynamic organization with a long tradition of moving in an independent sphere. Current membership tops 4300, of whom only half are members of ACS. This number includes 68 students and 325 emeriti. Almost a mirror image of ACS, the division has 23 local sections, called rubber groups, of which the largest are in Akron, Los Angeles, Chicago, Detroit, and locations making up the Southern Rubber Group.

The Rubber Division has its own system of courses and books; and a monthly journal, *Rubber Chemistry & Technology*, is sent free to members. The journal also has 1100 paid subscribers at $60 per year among companies and libraries. The division publishes monographs and meeting symposia independently as well as texts for its courses.

The elementary correspondence course often is taken by sales people and technical secretaries, and is an introduction to rubber science and terminology. More than 12,000 persons have taken it to date. The division soon will offer an intermediate course between the elementary course and the advanced course, which has become too advanced.

There are two national meetings in spring and fall. The fall 1982 meeting in Cleveland drew an attendance of 2000 and occupied four hotels. The division selected Toronto, Ont., for its spring 1983 meeting, May 9–12. The fall meeting will be in Houston, Oct. 25–27.

Marjorie E. Bauer opened the headquarters office 20 years ago at the University of Akron, Ohio 44325. It is she who collects annual dues of $15 for members and $3.00 for students. A full-time information scientist in the office performs computer searches of the literature and has access to libraries at the university and at the major rubber companies in the area. The only holdings of the office's own library are a collection of papers from past meetings and a complete run of *Rubber Chemistry & Technology*.

The division set out on a road separate from ACS in the 1920s owing to finances and a desire of members to meet more intimately among themselves. When meeting attendance had grown quite large, the leaders of that day realized they could hold their own meetings and operate independently on finances. Also, because informal meetings in hallways and hospitality suites are at least as important as the technical sessions, members wanted to be housed together in the same bloc of hotels.

The division retains a connection to ACS, participating in the Macromolecular Secretariat and sometimes appearing as cosponsor of other divisions' symposia at ACS national meetings.

age for a customer. Besides that, we have our technical service laboratory in Pittsburgh and a network of distribution centers throughout the eastern U.S. So our strategy will be service and a broad product line."

Among newcomers to Mobay's product line in the U.S. are the 3-methyl-2-thiazolidinethione accelerator for neoprene, intended to replace ethylenethiourea, and *N,N*-diisopropyl -2-benzothiazolesulfenamide, which Cyanamid discontinued. These products, like most of Mobay's line, will be imports.

As far as production in the U.S. is concerned, Mobay has begun to make an antiozonant, *N*-(1,3-dimethylbutyl)-*N'*-phenyl - *p*-phenylenediamine, and to formulate a plasticizer based on pentachlorothiophenol at its Bushy Park, S.C., plant. In addition, the company makes a bonding agent in New Martinsville, W.Va.

"This domestic production forms a base for our imported products," Rizzer says. Concerning the possibility of producing other rubber chemicals in the U.S. in the future, he says, "We're always thinking domestic. It's always in the back of our minds." □

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Europeans push antidumping tariffs Page 20

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NEWS

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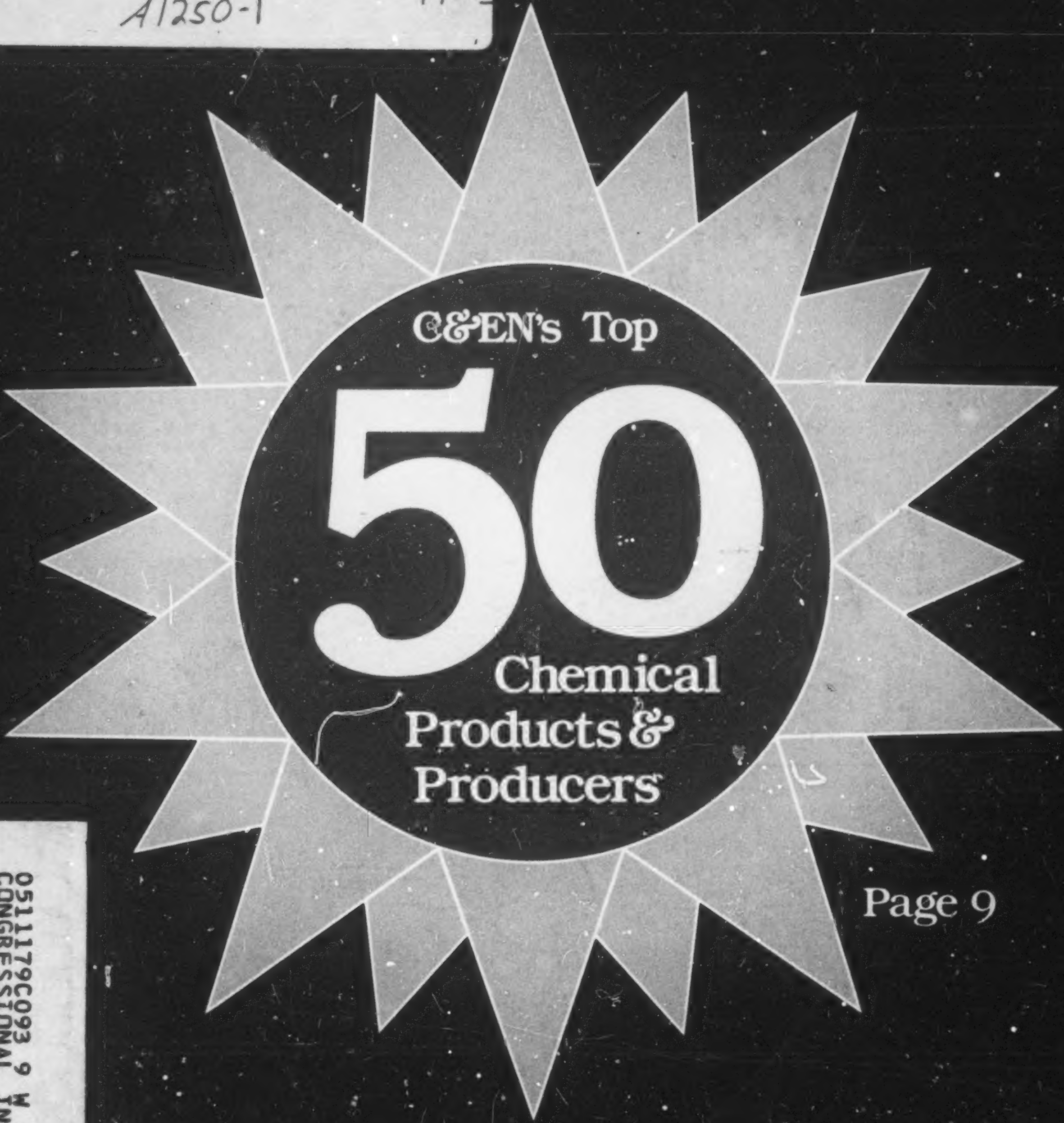

C&EN's Top

50 Chemical Products & Producers

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CHEMICAL & ENGINEERING NEWS

MAY 2, 1983

News of the Week

- **First-quarter earnings indicate chemical industry recovery from the recession will be gradual.** **Page 6**
- **GAF will liquidate by selling its chemicals business to Allied for $410 million.** **Page 7**
- **Chemical industry influenced government's decision to reject international system of premarket testing, subcommittee says.** **Page 7**
- **National Academy of Sciences elects 60 new members, 18 in chemistry or related fields.** **Page 8**

International

Rise in product dumping in EEC countries attributed to economic downturn by former CEFIC official in C&EN interview. **Page 20**

Government

Lack of toxicity data in premanufacture notifications required under TSCA may prompt Congress to amend the act. **Page 34**

Supreme Court says no to ban on restarting TMI reactor, yes to California moratorium on nuclear plants. **Page 35**

Technology

Commercial projects for space station are the goal of Booz-Allen as it hunts potential users with seed concepts. **Page 37**

The local chemical lab may be as popular as the small-town doctor if California entrepreneur's idea catches on. **Page 38**

Resin Rinse, a maintenance treatment to prevent fouling of resin beads, developed by Nalco Chemical. **Page 39**

AIC Award

Medalist Mary Good says the transition from professor to industry executive has not been difficult. **Page 40**

ACS News

Chemical education study implemented by ACS task force to parallel NAS study; both aim to influence federal spending. **Page 42**

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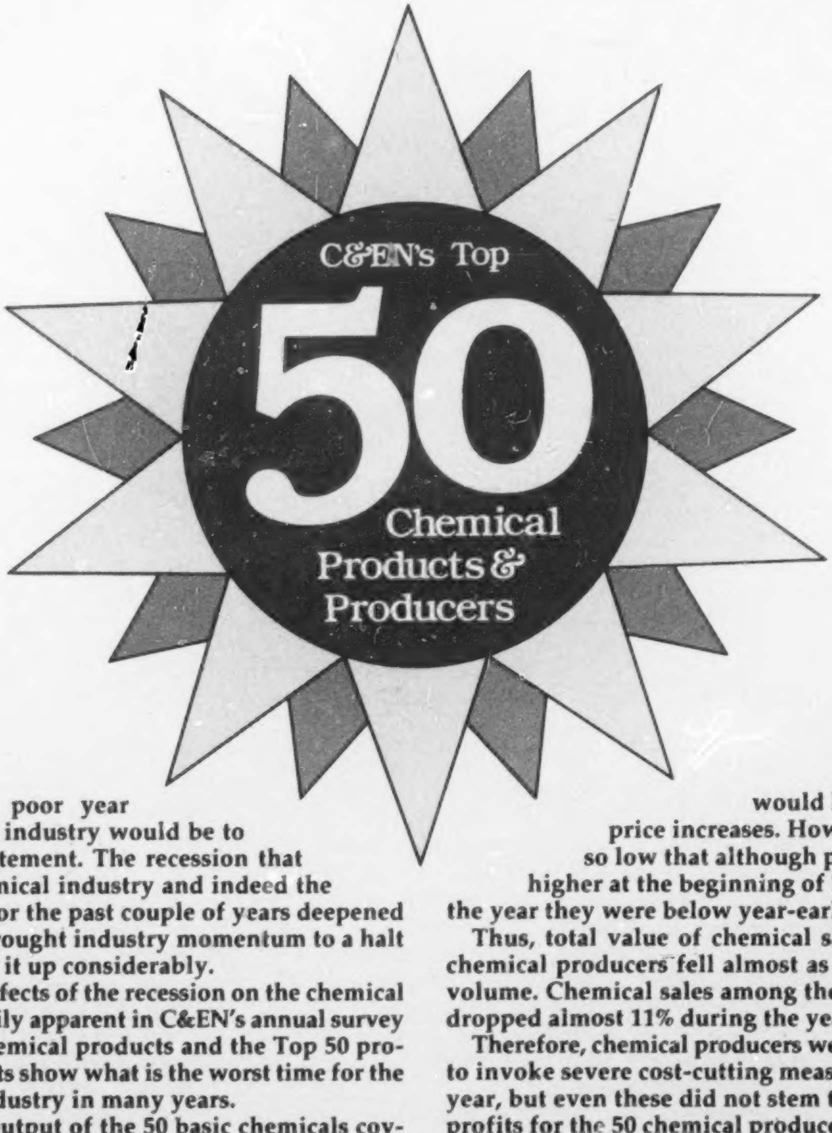
Top 50

C&EN's annual ranking of Top 50 chemical products and producers confirms recession's toll on production and profits. **Page 9**



C&EN's Top 50 Chemical Products & Producers

To call 1982 a poor year for the chemical industry would be to deal in understatement. The recession that gripped the chemical industry and indeed the U.S. as a whole for the past couple of years deepened to a point that brought industry momentum to a halt and even backed it up considerably.

The massive effects of the recession on the chemical industry are readily apparent in C&EN's annual survey of the Top 50 chemical products and the Top 50 producers. The results show what is the worst time for the U.S. chemical industry in many years.

For instance, output of the 50 basic chemicals covered in the survey dropped 14% in 1982 from 1981 after what now seems to be a moderate drop of only 1% in 1981 from the year before.

The production drop was pervasive with both inorganics and organics dropping to levels not seen since before 1977. Organics output fell 10% during the year and that of inorganics, which had suffered the most the year before, dropped 15%.

With the output of chemical products falling fast, the only way that producers could recoup their losses would have been through price increases. However, demand was so low that although prices began a little higher at the beginning of 1982, by the end of the year they were below year-earlier levels.

Thus, total value of chemical sales of the Top 50 chemical producers fell almost as fast as production volume. Chemical sales among the Top 50 producers dropped almost 11% during the year.

Therefore, chemical producers were left with having to invoke severe cost-cutting measures to salvage the year, but even these did not stem the tide. Operating profits for the 50 chemical producers were more than cut in half. And their operating profit margins dropped 4.0% in 1982 from 8.0% the year before; return on assets fell to 4.6% from 10.1%.

The only thing left is for chemical producers to look for better times in 1983. And it looks as though they may get them, in spite of what turned into a bad first quarter. Most analysts predict that although the first half may well be slow, the second half of 1983 will show very positive signs of improvement over 1982; indeed it could be a much more profitable year.

Basic chemical output fell third year in row

David Webber, C&EN New York

C&EN's Top 50 Chemical Products

A year ago the chemical industry learned to its shock that production of the 50 largest-volume chemical commodities in 1981 had declined for the second year in a row. Such a sequence of losses had never been recorded in a business full of people who until recently believed uninterrupted growth was their manifest destiny. Now, with a crashing 14% further production drop in 1982, the industry is riding a three-year losing streak.

But that's not the most disturbing picture to emerge from C&EN's annual survey of the Top 50 chemical products. A 14% decline is bad, but there are strong indications that this year's anticipated rebound will make up for a good share of that. What must be especially troubling to many in the industry, however, is that for the first time ever, production over a five-year span—from 1977 to 1982—actually shows a decline. Even for the 10-year period beginning in 1972, compounded annual growth in production has been a meager 1%. Such poor figures on long-term measurements can only reinforce the increasingly prevalent belief that the chemical industry is, by and large, maturing (C&EN, April 11, page 11).

The erosion of vitality has not been the result of a few, very-large-volume commodities having some bad years. The trend is pervasive. In 1982, 46 of the Top 50 chemical products registered production lower than the year before. By comparison, in 1981, 26 products had lower output than in 1980. Similarly, in the five-year period ending in 1982, 37 products showed a production loss. Last year, output of only 14 chemicals was down over the previous five years. And in the 10-year period ending in 1982, output of 20 of the 50 top products declined. In the comparable period ending in 1981, 10 showed a production drop.

The 14% output plunge of the Top 50 last year was part

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking or incomplete.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back for many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1982. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, production figures for 1981 that appear in the table on page 11 are different in some cases from those published in last year's Top 50 report. The final reports also can affect the rankings of chemicals. The 1981 rankings of 14 of the chemicals listed in the table, for example, are different from those in the similar table published by C&EN a year ago.

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks such as ethylene and propylene to downstream products such as vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, potash, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead-burned) dolomite is excluded in the calculations of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily, because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds.

Top 50 chemical output has declined over the past five years

Rank			Production				Average annual growth			
			Billions of lb		Common units[b]					
1982	1981[a]		1982	1981	1982	1981	1981–82	1980–81	1977–82	1972–82
1	1	**Sulfuric acid**	64.74	81.35	32,368 tt	40,675 tt	−20.4%	−8.1%	−3.1%	0.4%
2	4	**Nitrogen**	35.00	35.73	483 bcf	493 bcf	−2.0	2.9	7.8	9.5
3	2	**Ammonia**	30.99	38.08	15,494 tt	19,038 tt	−18.6	0	−2.5	0.2
4	5	**Oxygen**	29.22	35.02	353 bcf	423 bcf	−16.6	−1.9	−2.1	0
5	3	**Lime**[c]	28.40	37.78	14,202 tt	18,890 tt	−24.8	6.8	−5.6	−3.0
6	6	**Ethylene**	24.66	29.42	24,662 mp	29,418 mp	−16.2	2.6	−0.6	1.7
7	7	**Sodium hydroxide**	18.45	21.30	9,225 tt	10,652 tt	−13.4	−8.4	−3.3	−1.0
8	8	**Chlorine**	18.27	21.12	9,136 tt	10,560 tt	−13.5	−7.5	−2.9	−0.8
9	9	**Phosphoric acid**	17.10	19.83	8,552 tt	9,914 tt	−13.8	−9.4	−0.9	2.5
10	12	**Sodium carbonate**[d]	15.79	16.56	7,896 tt	8,281 tt	−4.7	0.1	−0.5	0.6
11	15	**Toluene**[e]	15.25	12.35	1,052 mg	852 mg	23.5	−16.2	−0.3	1.4
12	10	**Nitric acid**	15.24	18.08	7,621 tt	9,039 tt	−15.7	3.5	−0.9	−0.5
13	11	**Ammonium nitrate**[f]	14.67	17.58	7,344 tt	8,791 tt	−16.6	−3.7	0.4	0.7
14	14	**Propylene**	12.30	13.48	12,304 mp	13,482 mp	−8.8	−1.4	−1.6	3.8
15	13	**Urea**[g]	11.84	16.21	5,918 tt	8,103 tt	−27.0	3.5	5.9	5.6
16	16	**Ethylene dichloride**	9.99	9.97	9,985 mp	9,974 mp	0.2	−10.2	−1.9	2.5
17	17	**Benzene**	7.87	9.61	1,070 mg	1,307 mg	−18.1	−34.9	−7.0	−1.6
18	20	**Carbon dioxide**[h]	7.38	7.96	3,688 tt	3,982 tt	−7.4	7.0	5.5	8.6
19	18	**Methanol**	7.25	8.58	7,247 mp	8,576 mp	−15.5	19.9	2.3	1.8
20	19	**Ethylbenzene**	6.61	7.81	6,608 mp	7,812 mp	−15.4	2.2	−4.5	1.5
21	21	**Vinyl chloride**	6.50	6.87	6,495 mp	6,873 mp	−5.4	6.3	1.6	2.5
22	22	**Styrene**	5.87	6.68	5,865 mp	6,679 mp	−12.1	−1.1	−3.1	−0.1
23	23	**Xylene**	5.29	6.39	730 mg	881 mg	−17.1	−3.1	−2.7	−0.1
24	24	**Terephthalic acid**[i]	4.97	6.23	4,974 mp	6,234 mp	−20.2	3.0	−1.7	5.3
25	27	**Hydrochloric acid**	4.97	4.89	2,485 tt	2,444 tt	1.6	−15.8	−1.8	0.6
26	26	**Ethylene oxide**	4.87	5.11	4,874 mp	5,109 mp	−4.7	−2.1	2.2	2.1
27	25	**Formaldehyde**[j]	4.68	5.72	4,684 mp	5,720 mp	−18.2	3.0	−5.0	−1.9
28	30	**Ethylene glycol**	3.99	4.14	3,993 mp	4,142 mp	−3.6	−5.6	1.7	0.6
29	29	**Ammonium sulfate**	3.57	4.22	1,787 tt	2,111 tt	−15.4	−1.2	−3.9	−0.4
30	28	***p*-Xylene**	3.20	4.53	3,196 mp	4,532 mp	−29.4	6.9	0.1	3.8
31	32	**Acetic acid**	2.75	3.07	2,751 mp	3,074 mp	−10.4	3.3	1.4	2.1
32	31	**Cumene**	2.69	3.31	2,686 mp	3,309 mp	−18.7	−4.3	0.3	1.6
33	36	**Aluminum sulfate**	2.38	2.41	1,189 tt	1,206 tt	−12.5	−6.2	−1.1	0
34	34	**Carbon black**	2.29	2.73	2,290 mp	2,730 mp	−16.1	7.2	−7.2	−3.2
35	35	**Phenol**[k]	2.13	2.58	2.134 mp	2,578 mp	−17.4	0.4	−1.8	1.1
36	39	**Acrylonitrile**	2.02	2.00	2,016 mp	1,996 mp	1.0	9.1	4.1	6.1
37	40	**Vinyl acetate**	1.88	1.94	1,876 mp	1,936 mp	−3.1	0.7	3.4	4.5
38	33	**Butadiene**[l]	1.83	2.99	1,831 mp	2,986 mp	−38.8	6.7	−10.9	−6.4
39	37	**Sodium sulfate**[m]	1.79	2.33	893 tt	1,164 tt	−23.2	2.2	−5.7	−3.9
40	38	**Acetone**	1.76	2.14	1,757 mp	2,144 mp	−18.0	3.8	−4.6	0.1
41	41	**Calcium chloride**[n]	1.75	1.83	875 tt	917 tt	−4.4	13.1	−2.0	−2.9
42	43	**Propylene oxide**	1.48	1.73	1,477 mp	1,734 mp	−14.8	−1.9	−4.6	−0.3
43	44	**Isopropyl alcohol**	1.30	1.67	1,301 mp	1,669 mp	−22.2	−9.1	−7.2	−3.1
44	46	**Sodium silicate**	1.30	1.48	650 tt	738 tt	−12.2	−6.0	−3.1	−0.2
45	45	**Titanium dioxide**	1.28	1.50	641 tt	750 tt	−14.7	−4.7	−1.4	−0.8
46	42	**Cyclohexane**	1.27	1.82	1,272 mp	1,819 mp	−30.2	−7.4	−10.7	−5.7
47	47	**Sodium tripolyphosphate**	1.27	1.38	633 tt	689 tt	−8.0	−12.7	−2.5	−4.8
48	49	**Adipic acid**	1.20	1.21	1,197 mp	1,210 mp	−1.1	0.8	−4.9	−2.1
49	48	**Acetic anhydride**	1.06	1.25	1,061 mp	1,248 mp	−15.0	−15.0	−6.7	−3.9
50	50	**Ethanol**	1.02	1.32	1,022 mp	1,317 mp	−22.7	−9.2	−5.3	−5.8
		TOTAL ORGANICS IN TOP 50	**157.53**	**175.24**			**−10.1%**	**−0.5%**	**−0.4%**	**1.9%**
		TOTAL INORGANICS IN TOP 50	**320.72**	**378.05**			**−15.2%**	**−1.5%**	**−1.4%**	**0.7%**
		GRAND TOTAL OF TOP 50	**478.25**	**553.29**			**−13.6%**	**−1.2%**	**−1.1%**	**1.0%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons. c Except refractory dolomite. d Synthetic and natural. e All grades. f Original solution. g 100% basis. h All forms. i Includes both acid and ester without double counting. j 37% by weight. k Synthetic only. l Rubber grade. m High and low purity. n Solid and liquid. **Sources:** Bureau of the Census, Bureau of Mines, International Trade Commission, C&EN estimates

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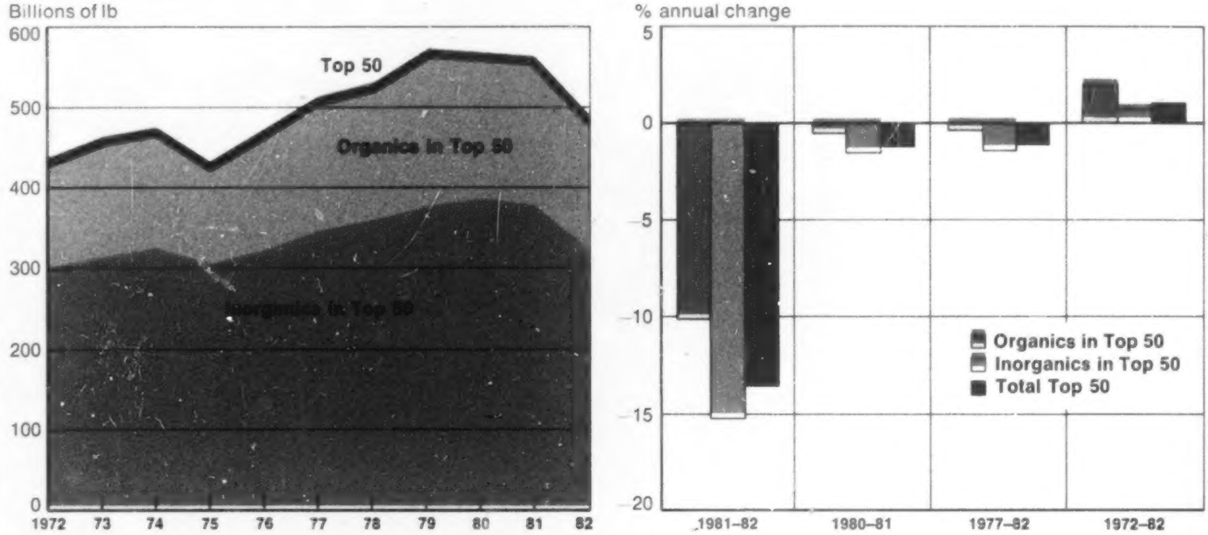
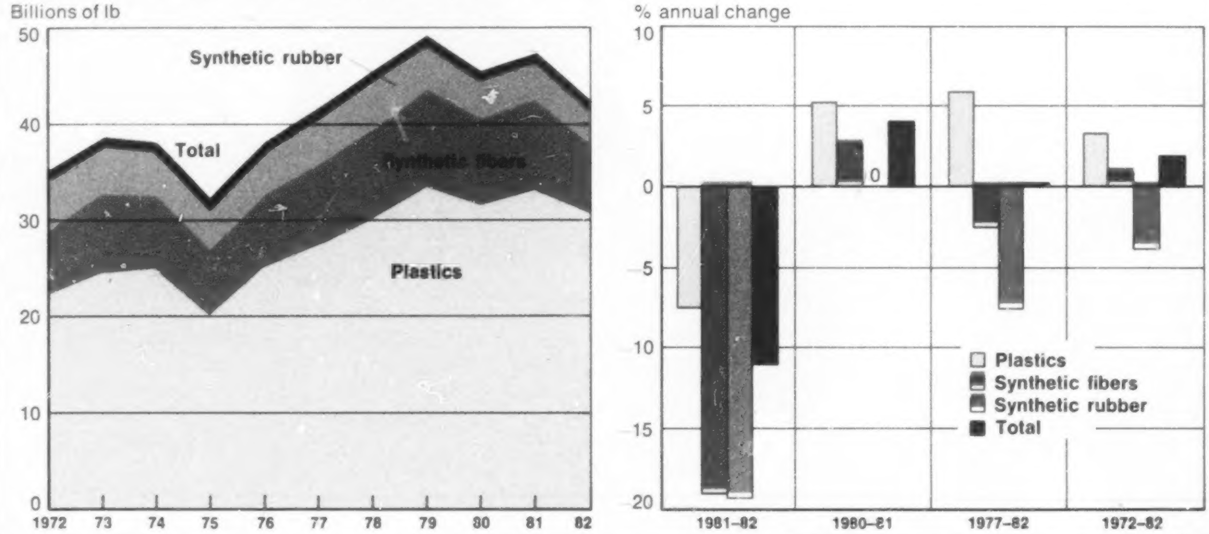
Production of basic chemicals plummeted in 1982 . . .



. . . as did output of plastics, fibers, and rubber



of an overall decline marked by a 16% decrease in the Federal Reserve Board's industrial production index for all basic chemicals. For many of the Top 50 products, the decline was severe: 35 registered double-digit percentage decreases from 1981, and output of 10 of those fell more than 20%.

To a great extent, last year's biggest declines came in products—lime, butadiene, sodium sulfate, isopropyl alcohol, cyclohexane, and ethanol—whose output has been shrinking for a decade or more anyway. But other big drops resulted from economic weaknesses that are more of the moment: sulfuric acid and urea, down 20% and 27%, respectively, because of another poor year for the fertilizer industry, and terephthalic acid and *p*-xylene, down 20% and 29%, respectively, because of another bad performance by polyester fibers (whose production was down 24% in 1982).

The widespread decreases in production hit inorganic chemicals hardest, as they did in 1981—down an average 15%. But organic chemicals, which declined less than 1% in 1981, hardly made it through the year unscathed. Overall, organics output dropped 10% in 1982.

The cause of this big decline in the organics sector is apparent in the performance of the end uses of many of them: plastics, synthetic fibers, and synthetic rubber products, all closely tied to the consumer economy. Output of plastics was down 8% overall; output of fibers fell 19%; and output of rubber dropped 19%.

The plastics slump affected the thermosets the most. Overall, their production declined an average of 14% in

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1982 slump affected production of nearly every polymer

Production	Billions of lb		Common units					Average annual growth			
	1982	1981	1982	1981	1980	1977	1972	1981–82	1980–81	1977–82	1972–82
PLASTICS (millions of lb)											
Thermosetting resins	**4.30**	**5.01**	**4,304**	**5,010**	**4,517**	**3,943**	**3,480**	**−14.1%**	**10.9%**	**1.8%**	**2.1%**
Phenolic and other tar acid resins	2.01	2.33	2,005	2,333	1,745	1,458	1,453	−14.1	33.7	6.6	3.3
Urea resins	1.00	1.17	996	1,165	1,311	963	739	−14.5	−11.1	0.7	3.0
Polyesters (unsaturated)	0.86	1.00	860	997	952	1,061	933	−13.7	4.7	−4.1	−0.8
Epoxies (unmodified)	0.29	0.34	286	336	323	261	184	−14.9	4.0	0.9	4.5
Melamine resins	0.16	0.18	157	179	186	200	171	−12.3	−3.8	−4.7	−0.9
Thermoplastic resins	**25.80**	**27.52**	**25,797**	**27,524**	**26,444**	**22,753**	**18,255**	**−6.3%**	**4.1%**	**2.5%**	**3.5%**
Low-density polyethylene	7.46	7.69	7,455	7,693	7,189	6,471	5,274	−3.1	7.0	2.9	3.5
Polyvinyl chloride and copolymers	5.33	5.71	5,328	5,707	5,485	5,253	4,259	−6.6	4.1	0.3	2.3
High-density polyethylene	4.89	4.70	4,886	4,695	4,531	3,652	2,325	4.1	3.6	6.0	7.7
Polystyrene and copolymers	4.65	5.47	4,653	5,474	5,540	4,630	4,671	−15.0	−1.2	0.1	0
Polypropylene and copolymers	3.48	3.96	3,475	3,955	3,699	2,747	1,726	−12.1	6.9	4.8	7.2
TOTAL[a]	**30.10**	**32.53**	**30,101**	**32,534**	**30,961**	**22,696**	**21,735**	**−7.5%**	**5.1%**	**5.8%**	**3.3%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.58**	**0.77**	**584**	**770**	**806**	**888**	**1,394**	**−24.7%**	**−4.5%**	**−8.1%**	**−8.3%**
Rayon	0.39	0.51	388	509	490	598	965	−23.5	3.9	−8.3	−8.7
Acetate[b]	0.20	0.26	196	261	316	290	429	−23.1	−17.4	−7.5	−7.5
Noncellulosics	**7.35**	**9.03**	**7,348**	**9,023**	**8,741**	**8,098**	**5,929**	**−18.6%**	**3.3%**	**−1.9%**	**2.2%**
Polyester	3.17	4.18	3,169	4,173	3,989	3,642	2,339	−24.0	4.7	−2.7	3.1
Nylon[c]	1.93	2.33	1,932	2,333	2,358	2,326	1,975	−17.2	−1.1	−3.7	−0.2
Glass fiber	0.90	1.04	899	1,041	867	787	572	−13.6	20.0	2.7	4.6
Olefin	0.72	0.79	724	785	748	634	417	−7.8	4.9	7.3	5.7
Acrylic[d]	0.62	0.69	624	691	779	709	626	−9.7	−11.3	−2.5	0
TOTAL[a]	**7.93**	**9.79**	**7,932**	**9,793**	**9,547**	**8,986**	**7,323**	**−19.0%**	**2.6%**	**−2.5%**	**0.8%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[e]	1.93	2.28	876	1,032	1,074	1,333	1,476	−15.4	−4.0	−8.1	−5.1
Polybutadiene	0.64	0.75	288	342	311	361	294	−14.7	9.9	−4.4	−0.2
Ethylene-propylene	0.27	0.39	123	178	144	158	90	−30.8	23.6	−4.9	3.2
Neoprene	0.26	0.32	119	143	151	165	f	−18.8	−5.3	−6.3	f
Nitrile	0.10	0.15	45	66	70	70	73	−33.4	−5.7	−8.5	−4.7
Other[g]	0.40	0.58	181	261	272	267	f	−30.0	−4.0	−7.5	f
TOTAL[a]	**3.60**	**4.46**	**1,632**	**2,021**	**2,022**	**2,416**	**2,417**	**−19.3%**	**0**	**−7.6%**	**−3.8%**

a Totals are for those products listed. Totals may not add because of rounding. b Includes diacetate and triacetate yarn. Does not include cigarette filters. c Includes aramid. d Includes modacrylic. e Excludes high-styrene latex. f Data for neoprene and "other" were combined in 1972. g Includes butyl, polyisoprene, chlorosulfonated polyethylene, polyisobutylene, and acrylo, fluoro, polysulfide, and silicone elastomers. Before 1982, butyl and polyisoprene were reported separately; they have been retroactively added to "other" here.

1982, and two resins—unsaturated polyester and melamine—now show a compounded decline over both the past five and the past 10 years.

Production of thermoplastics fell a relatively slight (on last year's terms) 6%, buoyed by a healthy 4% increase in high-density polyethylene output. But every other big resin registered a decline. Production of polypropylene, robust for a number of years, was down sharply, and that of polystyrene continued its losing ways. Production has been absolutely flat over the past 10 years.

In the synthetic fibers sector, results were even more dismal. The long-term decay of the cellulosics market accelerated with an average 25% drop in output last year. In the noncellulosics area, which had an overall decrease of 19%, cuts in production were substantial. Nylon's performance was bad enough to push its 10-year record to a decline. Output of acrylic fibers during the past decade has been flat. Overall, synthetic fiber output has barely grown at all since 1972.

The synthetic rubber sector maintained its part as sick man of the chemical industry last year. Except for ethylene-propylene rubber, whose output was down 31% in 1982, every synthetic rubber category has been declining for the past 10 years (C&EN, April 25, page 23). The worst is styrene-butadiene rubber, the major product, whose production was down 15% last year and down a compounded 5% for the 10-year period. And three categories—ethylene-propylene, nitrile, and others—all recorded production declines last year of more than 30%. □

Sales down at largest chemical producers

William J. Storck, C&EN New York

C&EN's Top
50
Chemical
Producers

Last year was marked by falling chemical production and prices brought on by weak demand both in the U.S. and in export markets, leaving the largest chemical producers in the U.S. in pretty sorry shape by year's end. And it has them looking longingly for a turnup later in 1983.

Chemical companies were affected during the year by a number of factors. On the demand side poor housing and automobile markets led to problems for a number of chemical products including fibers and plastics. In addition, the poor farm economy played havoc with the fertilizer industry. And the effect did not stop at commodity chemicals. It extended to specialties, which usually are not hurt by recessions.

As a result, production of chemicals and allied products for 1982 dropped 9% from the year before, and basic chemicals production fell 16%. The value of manufacturers' shipments for chemicals and allied products declined 3.5%; for basic chemicals, it was down 10.5%. Chemical exports fell 6% and the chemical trade surplus dropped 12% from 1981 levels.

The recession, quite naturally, led to cost cutting, payroll slashing, and shucking of unprofitable lines with little future—but to no avail. The companies' earnings from chemical operations still plummeted.

The incidence of poor results was not just widespread, it was universal. Every one of the 50 largest chemical producers (in terms of sales) had a decline in chemical sales in 1982 from the year before. And all but one—Ethyl—posted a drop in operating profits (sales minus costs of goods and administrative costs) from the year before. Combined chemical sales of the Top 50 producers fell 10.6% from 1981 to $100.6 billion.

However, when compared to the fall in operating profit, the 10.6% sales drop looks almost good. Among 44 companies at which chemical operating profits can be measured, this measure fell an average of 55.2% from 1981 to $3.79 billion. The result was that chemical operating profit margins were cut in half, dropping to 4.0% in 1982 from 8.0% the year before.

The cutting of operations and the low level of capital spending in the chemical industry also were apparent in results from chemical producers. Chemical assets among the 44 companies that provide them fell 2.2% in 1982 to $81.4 billion. As a result, chemical operating return on assets (operating profit as a percentage of chemical assets) decreased more than chemical operating profit margins, dropping to 4.6% in 1982 from 10.1% in 1981.

Three of the Top 50 companies are new to the list this year. Nalco Chemical has replaced Akzona, which, since it was acquired by Enka last year, no longer reports its U.S. results. Merck moved up to 49th place this year and Kaiser Aluminum & Chemical, because of a less than 1% drop in chemical sales during the year, rose to 50th place from 63rd last year.

A number of companies improved their rankings in 1982. W. R. Grace moved up to ninth place from 10th in 1981, Allied to 10th from 11th, Phillips to 11th from 12th, Eastman Kodak to 13th from 14th, Rohm & Haas to 17th from 18th, Texaco to 21st from 22nd, Ethyl to 22nd from 23rd, and Ciba-Geigy to 27th from 31st. In addition, Shell Oil, Mobil, Hercules, Ashland Oil, Union Oil of California, Standard Oil of California, Mobay, B. F. Goodrich, and Dow Corning all moved up on the list.

Only 10 companies dropped in rank in 1982. One of the largest drops was Tenneco, a company that shed much of its chemical operations during the year. It fell to 31st place in 1982 from 21st in 1981. Another big drop was for U.S. Steel, which fell to 32nd place from 24th place the year before. Other companies whose rank dropped were Celanese, Atlantic Richfield, Gulf Oil, American Cyanamid, Borden, International Minerals, Diamond Shamrock, and CF Industries.

There are some fuzzy areas in the Top 50 list. First of all, not every company that could be included is on the list, because of lack of reporting of chemical operations. Large chemical producers that do not break out their chemical sales include General Electric, Procter & Gamble, and now Akzona. Also, there is a problem of companies including in their chemical operations large volumes of nonchemical products. There are a number of such companies on the list.

Another problem is that some companies report some, but not all, of their chemical sales. PPG Industries, for instance, reports a chemical sales figure, but other chemical operations are included in its pigments operations, thus making them impossible to estimate. Another example of this is Occidental Petroleum, which before this year reported industrial chemical and agricultural chemical sales. This year, however, agricultural chemicals have been combined with the company's meat-packing operations to form a division called agribusiness. Because the agricultural chemical operations figures could not be obtained, C&EN could report only

All of Top 50 producers had sales drops in 1982

Rank 1982	Rank 1981[a]	Company	Chemical sales 1982 ($ million)	Change from 1981	Chemical sales as % of total sales	Industry classification	Chemical operating profit[b]	Change from 1981	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets	Chemical assets % of total assets	Operating return on chemical assets[d]
1	1	**Du Pont**	$10,841	−5.8%	32.5%	Diversified	$417	−63.7%	10.6%	3.8%	$7745	36.6%	5.4%
2	2	**Dow Chemical**	8,252	−12.1	77.7	Basic chemicals	226	−63.1	63.5	2.7	8124	68.8	2.8
3	3	**Exxon**	7,259	−14.0	7.1	Petroleum	47	−86.5	0.6	0.6	5047	8.1	0.9
4	4	**Monsanto**	5,737[e]	−9.1	90.7	Basic chemicals	497	−26.0	99.2	8.7	5234	86.1	9.5
5	5	**Union Carbide**	4,985	−13.7	55.0	Basic chemicals	294	−49.3	44.7	5.9	6027	57.3	4.9
6	7	**Shell Oil**	3,085	−14.4	15.4	Petroleum	−56	def	def	def	3841	18.0	def
7	6	**Celanese**	3,062	−18.4	100.0	Basic chemicals	39	−82.3	100.0	1.3	2862	100.0	1.4
8	8	**Standard Oil (Ind.)**	2,786	−9.8	9.4	Petroleum	133	−36.7	3.7	4.8	2530	10.6	5.3
9	10	**W. R. Grace**	2,654	−4.0	43.2	Specialty chemicals	303	−23.5	50.2	11.4	1608	34.5	18.8
10	11	**Allied**	2,407	−13.7	39.0	Diversified	105	−50.2	13.4	4.4	1726	27.5	6.1
11	12	**Phillips Petroleum**	2,356	−4.6	15.0	Petroleum	23	−83.6	1.0	1.0	1563	14.9	1.5
12	9	**Atlantic Richfield**	2,242	−18.1	8.3	Petroleum	−96	def	def	def	2608	12.1	def
13	14	**Eastman Kodak**	2,151	−8.4	19.9	Photo equipment	205	−29.1	11.0	9.5	2001	19.3	10.2
14	15	**Mobil**	2,148	−7.6	3.3	Petroleum	6	−95.1	0.1	0.3	2075	5.8	0.3
15	16	**Hercules**	2,040	−10.3	82.6	Basic chemicals	75	−55.9	65.8	3.7	1468	90.4	5.1
16	13	**Gulf Oil**	2,006	−18.3	6.6	Petroleum	−329	def	def	def	1232	6.6	def
17	18	**Rohm & Haas**	1,727	−1.9	94.5	Basic chemicals	156	−16.6	98.7	9.0	1008	90.7	15.5
18	17	**American Cyanamid**	1,698[e]	−12.7	49.2	Basic chemicals	100	−49.5	43.4	5.9	1308	56.5	7.6
19	19	**Stauffer Chemical**	1,618	−6.3	100.0	Basic chemicals	285	−7.3	100.0	17.6	1756	100.0	16.2
20	20	**American Hoechst**	1,506[e]	−6.4	100.0	Basic chemicals	na	na	na	na	na	na	na
21	22	**Texaco**	1,497	−16.7	3.2	Petroleum	−20	def	def	def	953	4.5	def
22	23	**Ethyl**	1,411[e]	−6.9	87.4	Basic chemicals	161	4.5	84.5	11.4	959	86.7	16.8
23	28	**Air Products**[f]	1,359	−0.2	86.6	Basic chemicals	189	−4.2	93.7	13.9	1596	73.6	11.8
24	27	**FMC**	1,319	−4.6	37.7	Machinery	149	−23.4	81.7	11.3	1084	39.2	13.7
25	31	**Ciba-Geigy**	1,285	−0.9	68.0	Specialty chemicals	na	na	na	na	na	na	na
26	26	**Occidental Petroleum**	1,260[g]	−11.5	6.7	Petroleum	15	−86.4	0.8	1.2	1209	8.8	7.1
27	25	**Borden**	1,220[e]	−14.4	29.7	Dairy products	86	−37.7	29.5	7.0	1271	49.1	6.8
28	30	**Ashland Oil**	1,197	−10.0	13.1	Petroleum	28	−31.7	8.3	2.3	402	9.5	7.0
29	33	**Union Oil of Calif.**	1,153	−7.6	10.6	Petroleum	90[h]	−19.3	11.1	7.8	671	7.9	13.4
30	32	**Mobay**	1,132	−9.4	100.0	Basic chemicals	3[h]	−94.6	100.0	0.3	1213	100.0	0.3
31	21	**Tenneco**	1,108	−7.5	7.4	Petroleum	15	−53.1	0.8	1.4	963	6.2	1.6
32	24	**U.S. Steel**	1,077	−24.6	5.7	Steel	−31	def	def	def	592	3.0	def
33	34	**Standard Oil of Calif.**	1,047	−14.1	3.0	Petroleum	−16[h]	def	def	def	825	4.0	def
34	38	**B. F. Goodrich**	1,015	−3.1	33.8	Rubber products	1	−96.3	def	0.1	1186	50.0	0.1
35	29	**International Minerals**[i]	1,013	−17.4	64.9	Agri. chemicals	169	−43.0	79.1	16.7	1345	69.3	12.6
36	36	**Olin**	1,012	−6.0	55.5	Basic chemicals	22	−53.7	16.6	2.2	914	61.7	2.4
37	35	**Diamond Shamrock**	996	−12.7	31.3	Petroleum	83	−44.9	34.2	8.3	1024	32.1	8.1
38	37	**CF Industries**	919[e]	−12.8	100.0	Agri. chemicals	−38	def	def	def	1008	100.0	def
39	41	**BASF Wyandotte**	895	−7.5	100.0	Basic chemicals	−3	def	def	def	735	100.0	def
40	39	**PPG Industries**	893	−11.8	30.1	Glass products	39	−67.5	16.4	4.4	1045	32.0	3.7
41	40	**Williams Cos.**	828[e]	−15.9	49.0	Agri. chemicals	−30	def	def	def	981	51.7	def
42	42	**Reichhold Chemicals**	815	−14.2	100.0	Basic chemicals	17	−52.8	100.0	2.1	356	100.0	4.8
43	43	**Lubrizol**	812	−9.7	100.0	Specialty chemicals	103	−34.4	100.0	12.7	569	100.0	18.1
44	44	**Eli Lilly**	789	−5.8	26.6	Drugs	147	−12.0	20.8	18.6	838	26.6	17.5
45	45	**National Distillers**	758	−10.9	41.4	Alcoholic beverages	58	−49.1	50.9	7.7	614	35.9	9.4
46	46	**Farmland Industries**	664	−18.6	11.8	Agri. supplies	−8	def	def	def	486	29.3	def
47	49	**Dow Corning**	663	−8.2	100.0	Specialty chemicals	53[h]	−30	100.0	8.0	na	na	na
48	51	**Nalco Chemical**	644	−3.4	100.0	Specialty chemicals	99	−18.9	100.0	15.4	465	100.0	21.3
49	53	**Merck**	644	−3.0	21.0	Drugs	60	−18.1	9.9	9.3	566	18.6	10.6
50	63	**Kaiser Aluminum**	642	−0.3	22.1	Nonferrous metals	44	−53.0	80.0	6.9	519	14.2	8.5

a Revised. **b** Operating profit defined as sales less administrative expense and cost of selling. **c** Operating profit as a percentage of chemical sales. **d** Operating profit as a percentage of identifiable chemical assets. **e** Chemical sales include significant amounts of nonchemical products. **f** Fiscal year ended Sept. 30, 1982. **g** Does not include all chemical products. **h** Chemical net profit. **i** Fiscal year ended June 30, 1982. **na** = not available. **def** = deficit.

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Leading companies in chemical profits, assets, and profitability

Rank		Operating profit ($ millions)		Operating profit margin[a]		Chemical assets ($ millions)		Return on chemical assets[b]
1	Monsanto	$471	Eli Lilly	18.6%	Dow Chemical	$8124	Nalco Chemical	21.3%
2	Du Pont	417	Stauffer Chemical	17.6	Du Pont	7745	W. R. Grace	18.8
3	W. R. Grace	303	International Minerals	16.7	Union Carbide	6027	Lubrizol	18.1
4	Union Carbide	294	Nalco Chemical	15.4	Monsanto	5234	Eli Lilly	17.5
5	Stauffer Chemical	285	Air Products	13.9	Exxon	5047	Ethyl	16.8
6	Dow Chemical	226	Lubrizol	12.7	Celanese	2862	Stauffer Chemical	16.2
7	Eastman Kodak	205	W. R. Grace	11.4	Atlantic Richfield	2608	Rohm & Haas	15.5
8	Air Products	189	Ethyl	11.4	Standard Oil (Ind.)	2530	FMC	[illegible]
9	International Minerals	169	FMC	11.3	Gulf Oil	2075	Union Oil of Calif.	13.4
10	Ethyl	161	Eastman Kodak	9.5	Eastman Kodak	2001	International Minerals	12.6
11	Rohm & Haas	156	Merck	9.3	Stauffer Chemical	1756	Air Products	11.8
12	FMC	149	Rohm & Haas	9.0	Allied	1726	Merck	10.6
13	Eli Lilly	147	Monsanto	8.7	W. R. Grace	1608	Eastman Kodak	10.2
14	Standard Oil (Ind.)	133	Diamond Shamrock	8.3	Air Products	1596	Monsanto	9.5
15	Allied	105	Dow Corning	8.0	Phillips Petroleum	1563	National Distillers	9.4

a Chemical operating profit as a percentage of chemical sales. b Chemical operating profit as a percentage of chemical assets.

the industrial chemical operations figures. Because of this, Occidental's chemical sales figures are much lower than last year—and to avoid confusion, the company's 1982 chemical sales figure was compared only to the comparable one for 1981. In addition, Occidental's 1981 rank was restated as if agricultural chemical sales had been eliminated. This lowered the company's chemical ranking on paper to 26th from 12th place as reported last year.

Thus, with these caveats in mind, it must be remembered that the rankings and, indeed, many of the figures from operations are only approximate. Therefore, they should be used only as a general guide to the chemical performance of the companies. □

Oil companies come in poor third in chemical performance

The 1982 recession hit everyone that had interests in chemicals, but it hit the oil companies harder than it did chemical firms or the diversified companies.

Although chemical companies did not lead in all categories, they at least turned in a respectable performance, vying with the diversifieds for top honors.

For comparison, 44 of the 50 firms that reported their chemical results can be used in a consistent manner. This involves similar reporting of chemical sales, assets, and operating profits.

Combined sales of the 44 companies were $93.8 billion, a decrease of 11% from 1981. Their chemical operating profits totaled $3.79 billion, down 55% from the year before. And their chemical assets amounted to $81.4 billion, down 2% from 1981.

Of the 44 firms, 19 were classified as chemical companies with combined chemical sales of $41.5 billion, or 44% of the total. The 12 oil companies had combined sales of $27.9 billion, or 30% of the total. And the 13 remaining companies had combined sales of $24.4 billion, or 26% of the total.

Chemical sales for the 19 chemical companies fell an average of 11% in 1982, right on the average for the total group of 44 companies. Sales for the diversified and other companies dropped an average of 9%. But for the oil companies, chemical sales were off an average of 13% from the year before.

Although the group of chemical companies was in the middle in sales declines last year, their 41% drop in chemical operating profit to $5.7 billion was not so bad as for the other groups. The oil companies showed a combined $151 million deficit in 1982. And the other companies had chemical operating profits of $3.8 billion, off 52% from 1981.

The asset decline, however, for chemical companies was greatest of the three groups. Whereas chemical assets for this group dropped 2.5% to a total of $38.3 billion, the oil companies' chemical assets fell 2.3% to $23.4 billion. The other companies' chemical assets fell 1.4% to $19.7 billion.

$ Billions	Chemical sales	Change from 1981	Chemical operating profits	Change from 1981	Chemical profit margin[a]	Chemical assets	Change from 1981	Chemical return on assets[b]
19 chemical companies[c]	$41.48	−11%	$2.66	−41%	5.7%	$38.32	−2.5%	7.0%
12 oil companies[c]	27.94	−13	−0.15	def	def	23.45	−2.3	def
13 other	24.40	−9	1.27	−52	5.2	19.67	−1.4	6.5
TOTAL[c]	**$93.82**	**−11%**	**$3.79**	**−55%**	**4.0%**	**$81.44**	**−2.2%**	**4.6%**

a Chemical operating profits as a percentage of chemical sales. b Chemical operating profits as a percentage of chemical assets. c Four chemical companies—Mobay, Ciba-Geigy, American Hoechst, and Dow Corning—and two oil companies—Standard Oil of California and Union Oil of California—have been excluded. def = deficit.

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Surge in Dumping Plagues European Chemical Federation

Former CEFIC official cites economic downturn as reason for rises in unfair trade practices and imposition of antidumping duties

Dermot A. O'Sullivan, C&EN London

In the Brussels headquarters of the Commission of the European Communities, someone has affixed to one of the doors a cardboard sign that reads "No dumping." Though put there as a somewhat facetious gesture, it serves as a reminder to visitors that they are at the nerve center of activities surrounding investigation of alleged unfair trading practices affecting the 10 member countries of the European Economic Community.

Dumping refers to a company's selling product in another country at prices less than those charged in the country of origin. Under the international trading rules of the General Agreement on Tariffs & Trade (GATT), for dumping in its total sense to occur, there must be injury to local producers arising from the low-priced imports. As a defensive countermeasure, companies that see their business harmed by the imports seek a compensatory antidumping duty to offset the price differential.

Sensitized by the worldwide economic slowdown, EEC has been the target of a wide variety of dumped products. In recent months, these have ranged from louver doors originating in Malaysia, to outboard motors arriving from Japan, and sanitary ware from Czechoslovakia and Hungary. On occasions, as in the case of steel and food products, imposition of antidumping duties has given rise to acrimonious exchanges between trading partners transcending beyond the commercial level to the political arena.

The focal point of dumping allegations arising from individual EEC companies or trade associations is the Commercial Defense Office of the EC Commission's External Relations Directorate. Acting on these allegations, staff members sift through the evidence, contact companies on both sides of the case whenever possible, and decide whether dumping is taking place.

The first step is publication of a notice that an investigation has been launched. Interested parties have 30 days in which to make their views known to the commission. Then follows the investigation proper, which can take about six months depending on the complexity of the case. If dumping is judged to occur, a provisional duty is imposed. Alternatively, the "offending" parties may adjust upward their selling price in EEC, and the commission withdraws its case. After setting a provisional duty, there follows a period of fine tuning leading to imposition of a definitive duty. This must be applied within 12 months of the start of a case.

The European Council of Chemical Manufacturers' Federations (CEFIC) is the channel through which most of the dumping complaints involving chemicals reach the commission. Since joining CEFIC in 1979 as trade and commercial affairs coordinator, Gareth H. Davies has been responsible for screening these complaints before passing them on.

A few weeks ago, Davies retired from CEFIC and was succeeded by Michael Cockburn. Before stepping down, he shared with C&EN's O'Sullivan some of his experiences and thoughts after nearly four years performing a difficult task.

C&EN: During your time with CEFIC, it seems that you have been heavily involved with dumping complaints.

Davies: I came in September 1979, and by September 1980 I was up to my neck in my first six petrochemical dumping cases. Since I've been here, we've looked at about 50 cases.

C&EN: How does that compare with earlier years?

Davies: Before I came, CEFIC had about five cases in eight years.

C&EN: Has the upswing in antidumping activity been a reflection of the economic downturn?

Davies: It has been a direct effect of the economic situation. When the economy begins to pick up again, concern over dumping undoubtedly will lessen.

C&EN: Have changes in the parity between major currencies also had some influence?

Davies: Yes, coupled with declining demand both in Western Europe and the U.S., there has been a period when the dollar was weak. The relatively strong dollar in recent months has been in Europe's favor. It's harder for a producer to sell material in areas of weaker currencies. The strength of the dollar has reinforced the antidumping measures that have been taken.

C&EN: Do you see these antidumping measures as something of a panacea?

Davies: We never fool ourselves that an antidumping duty is going to solve our problems. What it does do is give us an opportunity to try to improve the situation.

C&EN: Have there been any followup studies to measure what the effects have been of antidumping duties coming into force?

Davies: The first crude analysis shows that even the initiation of an antidumping action is sufficient to create a pause in the activity. At worst, you can say that antidumping actions as a whole have stopped the slide into disaster.

C&EN: Looking at the antidumping duties that the EC Commission has applied to chemicals, there appears to be a wide gap between the dumping price margins that have been claimed and the final level of duty applied.

Davies: You do find that there is a discrepancy between a dumping margin of, say, 50%, and a 10% applied dumping duty. This is because the commission, while acknowledging that there was dumping, may decide that the amount of injury suffered was far less than the dumping margin would indicate. It's getting tougher to measure this when you have a product with a large overcapacity. I have the greatest deal of sympathy for the commission.

C&EN: CEFIC took issue with the EC Commission when it imposed a 4% preliminary dumping duty on U.S. styrene.

Davies: We got mad about that. A 4% duty was so derisory that it just was not worth having. Our position was that the duty was so ridiculously low it could tempt people to jump over it and come in. It was the one occasion where we said publicly that we would try to get retroactive duties applied. As it was, the final definitive duty of 14.8% was more satisfactory, although some of the exporting companies were excluded.

C&EN: What does CEFIC do when it gets a dumping complaint from a company or group of companies?

C&EN staff photo

We don't think that dumping actions have soured relations with our trading partners

Davies: We look for five things. One is the action affecting a major proportion of EEC industry; second, is there dumping?; third, is there injury?—dumping of itself is not enough; fourth, evidence to back up the claim; and fifth, a short statement from each company about its individual injury. The companies also must provide us with such statistics as imports, share of the market, capacity utilization, etc. To get the whole picture, we must ask a lot of questions. We must satisfy ourselves that there is enough to go on before we go to the commission.

C&EN: On average, how long does it take to get all the information together?

Davies: It depends. We had a case through in a month when there was a limited number of producers. If there are many, it lengthens the time.

The normal situation is that if people were to come to us today, say five or six producers of a major product, we would send out our questionnaire seeking the bare bones of the case, and asking all producers if they are interested in taking part.

Collection of the information takes us anywhere from a week to three months. If we have what looks like a case, we tell the commission that we have a draft case we wish to present and ask for their views. The commission doesn't help us write a case; that would be totally wrong. But it advises whether the evidence in hand is sufficient or, perhaps, lacking. That may add a further month.

C&EN: It's surprising that any of these dumping cases ever come about, considering the machinery involved in their preparation.

Davies: It's a gigantic administrative burden. It really is. There is nothing so bad as an antidumping case. A lot of it is plain number-crunching. But it does take a lot of time because of the sheer weight of the paperwork. And there are practical problems, like estimating consumption and estimating the free market of a product. There can be quite contradictory evidence of this sort of thing.

And there is another problem. Although certain items of antidumping evidence plainly are confidential, some companies are oversecretive and spoil their own case. CEFIC tries to keep the evidence as open as possible. It takes time arguing with the complainants that it is to their advantage to make evidence available.

C&EN: During the preparation of a case, might this be taken as an opportunity for competitors to share information, thereby getting around some of the competition rules set out in the Rome treaty when EEC was created?

Davies: No. CEFIC is very, very careful about this. Sometimes, we have to be the confidential clearinghouse of information. Individual companies will send us facts that we can't divulge to other companies. People understand that CEFIC is the repository of a lot of confidential information. Companies come to us not as a means of fixing prices, but in search of survival.

C&EN: CEFIC appears to have had a good batting average on the dumping complaints sent to the commission.

U.S. is target of many CEFIC antidumping actions

Product	Country of origin	Investigation launched	Status
Acrylonitrile	U.S.	April 1982	Case closed
Barium chloride	China, East Germany	August 1982	Continuing
Bisphenol A	U.S.	April 1982	Provisional duty of 37.6%, January 1983
Catalyst for fluid cracking	U.S.	February 1981	Price adjusted, case closed
Cellulosic resins	U.S.	November 1982	Price adjusted, case closed
Choline chloride	East Germany, Romania	April 1983	Continuing
Copper sulfate	Czechoslovakia, Yugoslavia, U.S.S.R.	June 1982	Definitive duty of 19.5%, March 1983
Decabromodiphenylether	U.S.	December 1981	Price adjusted, case closed
DNBP herbicide	Romania	December 1978	Definitive duty of 40%, May 1979
Hexamethylenetetramine	Czechoslovakia, East Germany, Romania, U.S.S.R.	August 1982	Provisional duty on product from East Germany and U.S.S.R., February 1983; cases against Czechoslovakia, Romania dropped
Lithium hydroxide	U.S., U.S.S.R.	1978	Provisional duty October 1979. Being re-examined
Methylamines	East Germany, Romania	March 1982	Definitive duty of 28.8% on East German product, case against Romania dropped
Oxalic acid	China, Czechoslovakia, East Germany, Hungary	September 1981	Definitive duty of 34.2% on China product May 1982, cases against Czechoslovakia, East Germany, Hungary dropped
Paracetamol	China	December 1981	Price adjusted, case closed
Perchloroethylene	Czechoslovakia, Romania, Spain, U.S.	May 1982	Price adjusted, case closed
Phenol	U.S.	March 1981	Definitive duty ranging from 6.5 to 14.1%, January 1982
Polyethylene, low-density	Czechoslovakia, East Germany, Poland, U.S.S.R.	September 1982	Continuing
Polyvinyl chloride	Czechoslovakia, East Germany, Hungary, Romania	December 1981	Price adjusted, case closed
Soda ash (light)	Bulgaria, East Germany, Poland, Romania, U.S.S.R.	November 1978, reopened April 1982	Definitive duties February 1983, amounts vary by country of origin
Soda ash (heavy)	U.S.	June 1982	Definitive duty of about $24 per ton, March 1983. Some companies exempt
Styrene	U.S.	July 1980	Definitive duty of 14.8%, June 1981
Thiophene	U.S.	May 1982	Price adjusted, case closed
Trichloroethylene	Czechoslovakia, East Germany, Poland, Romania, Spain, U.S.	October 1981	Price adjusted, case closed
Vinyl acetate	U.S.	July 1980	Definitive duty of 14.3%, May 1981; lower duty applies to some companies
Xanthane gums	U.S.	September 1982	Continuing
Xylene, ortho and para	U.S.	November 1980	Definitive duty of 14.47% on *o*-xylene, September 1981, and of 14.7% on *p*-xylene, October 1981

Davies: So far, every case has shown that there has been both dumping and injury.

C&EN: Has CEFIC ever turned away a case?

Davies: Some we have turned down flat. Some have been thrown back to the producers several times when there was lack of evidence. A marketing manager who comes and says he knows that the competition is dumping must prove it. The fact that CEFIC passes on a complaint to the commission doesn't add any more weight to it. We have got to give the commission evidence.

C&EN: What reactions have you had from companies or countries that have been targeted in your complaints?

Davies: We are criticized sometimes for being too quick with these dumping actions. People say to us, "Isn't there a better way of doing this? Could you talk to us before going ahead?"

We have turned down this suggestion. If you start that, you find that you are negotiating. CEFIC has no rights to negotiate. We cannot be placed in the situation of arbitrator.

One thing that has pleased us is that we don't think that these dumping actions have soured commercial relations with our trading partners. We have talked to the Chemical Manufacturers Association about this, noting that it is the only route we have of removing a distortion of trade. We believe it has been accepted in those terms by most U.S. firms.

C&EN: Might there be an element of protectionism behind the moves?

Davies: In our view, there is a very big difference between protectionism and defensive measures. We are not protectionists. Defensive, yes.

An idea we are anxious to get across is that we are not accusing other countries or companies of being international criminals. We simply are saying that some of these have been dumping, often inadvertently. And the only means whereby we can apply corrective measures is by going to the commission. □

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C&EN's Second 50
chemical producers Page 33

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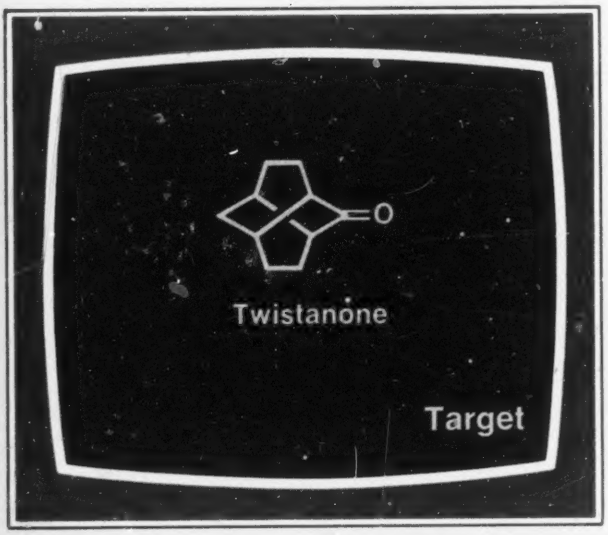
CHEMICAL & ENGINEERING NEWS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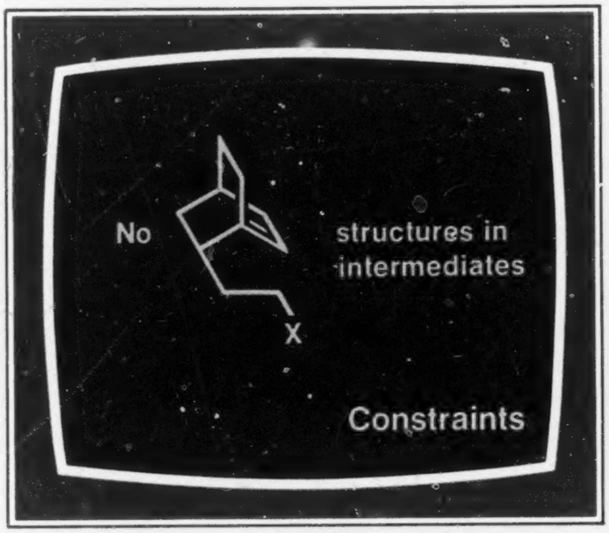
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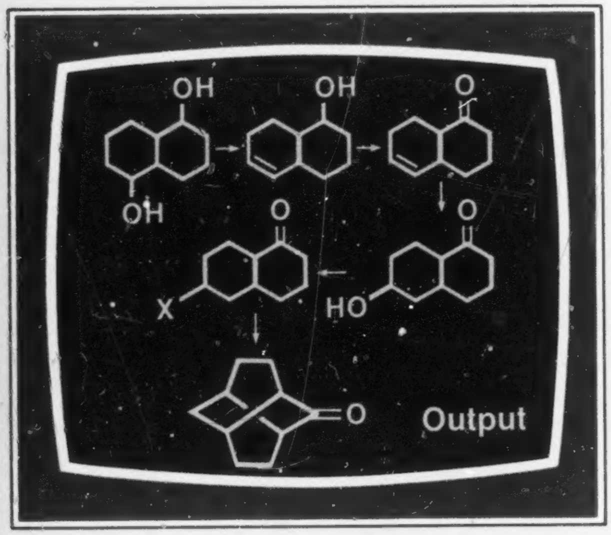
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COMPUTERS IN CHEMISTRY— MANAGING A REVOLUTION

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MAY 9, 1983

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- **The Commerce Department would be replaced by a Department of Trade under a new Administration proposal.** **Page 5**
- **Emphasis of man-made fibers R&D will shift to new products and process variants.** **Page 5**
- **Aerosol production in 1982 declined 4.5% from 1981 output, hitting a new low.** **Page 6**
- **Proposed sale of Kuwaiti ammonia to West Germany's Hoechst would be first European chemical market for the Mideast country.** **Page 6**

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Special Report

Organic synthesis by computer: one system, displaying graphical images, uses retrosynthetic pathways to identify precursors. **Page 22**

Business

Sales of C&EN's Second 50 chemical firms, usually resistant to recession, were down 6% in 1982, operating profits, 40%. **Page 33**

International

Japanese chemical makers are optimistic that the economy will improve and crude oil prices will drop. **Page 38**

Government

EPA's R&D office suffers from funding cutbacks, lack of direction; CAS may play role in patent office automation. **Page 40**

Science

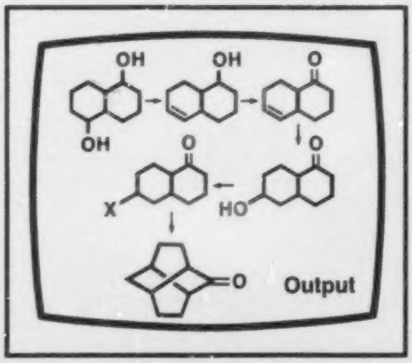
Chemists are using mathematicians' tools such as graph theory and topology to classify molecular structure, properties. **Page 45**

Science Policy

NAS president Frank Press cites the politicization of science in government, national security issues as prime concerns. **Page 49**

Education

Blue-ribbon panel on quality of U.S. education blasts mediocrity of secondary school curricula, substandard teaching. **Page 50**



News Focus

Advent of the computer is changing the practice of chemistry toward a more mathematical basis. Page 7

Sales Down at Medium-Sized Chemical Firms

Second 50 firms recorded combined sales last year down 6%, operating profits off 40%; profitability also dropped sharply

William J. Storck, C&EN New York

The decline that befell the chemical industry in 1982 did not skip over medium-sized chemical producers as such declines often have in the past.

The more specialized companies, with generally higher value-added products, that make up C&EN's list of Second 50 chemical producers (ranked 51 through 100 in terms of chemical sales) normally find themselves more recession-resistant than the Top 50 producers. And to a certain extent, they are. However, in 1982, though their sales and operating profits were not down so much as those of the Top 50 (C&EN, May 2, page 9), they can take small comfort.

Combined sales for the Second 50 companies were down last year about 6% from 1981 to about $18.6 billion. Their combined chemical operating profits (for those that reveal such data) were just $954 million, down 40% from 1981. Based on available data that are comparable year to year, identifiable chemical assets fell 1% from 1981 to $11.6 billion.

As a result, profitability measures suffered in 1982. Chemical operating profit margins for the group dropped to an average of 7.1% in 1982 from 11.0% the year before, and operating return on assets for chemicals fell to 8.2% from 13.7% in 1981.

Of the 50 companies, 32 recorded sales declines in 1982 from 1981. And of the 39 companies that report operating profits from chemicals, 29 had either declines in chemical profits or their chemical operations showed deficits in 1982.

Second 50 firms performed better than Top 50

There was little to cheer about in the chemical industry last year, but the group of companies that make up the Second 50 chemical producers can say that, as a group, they did fare a little better than the companies that make up the Top 50 list.

In terms of performance, companies making up the Second 50 posted an average chemical sales decline of 7% in 1982 from the year before. Chemical sales at the Top 50 fell 11% from 1981.

The Second 50 group consistently has turned in a better performance than the Top 50, perhaps because the medium-sized producers are not so encumbered with the highly cyclical commodity chemicals that dominate many of the firms' products in the larger group.

However, even the Second 50 were not immune to recession last year. Besides the 7% drop in chemical sales, chemical operating profits fell 40% from the year before.

The smaller firms also were able to hold their asset base a little better than the larger companies in a year of little capital spending. Identifiable chemical assets for the Second 50 dropped 1% from 1981, whereas at the larger firms the average fell a little more than 2%.

The smaller firms also outperformed the larger in profitability ratios. Chemical operating profit margins for the Second 50 averaged 7.1% in 1982, against a margin of 4.0% for the Top 50.

And operating return on assets for chemicals averaged 8.2% for the Second 50, and 4.6% for the Top 50.

This year, the number of chemical companies on both lists was the same at 23, as some of the companies on the Top 50 were reclassified as diversified. Petroleum companies on the Top 50 list outnumber those on the Second 50 14 to eight. The diversified companies among the Second 50 number 19; only 13 of the Top 50 are classified as diversified or other.

Eight of the Second 50 companies are owned by foreign interests, but just four of the Top 50 fall into this category.

	Second 50	Top 50	Combined 100
Chemical sales, change from 1981	−7%	−11%	−10%
Chemical operating profits, change from 1981	−40	−55	−53
Chemical assets, change from 1981	−1	−2	−2
Chemical operating profit margin, 1982	7.1	4.0	4.4
Return on identifiable chemical assets, 1982	8.2	4.6	5.1
	Number of companies on list		
Chemical companies	23	23	46
Petroleum and natural gas producers	8	14	22
Diversified and other	19	13	32
Foreign owned[a]	8	4	12

[a] Also included in above categories.

Second 50 chemical producers generally had lower sales in 1982

Rank 1982	Rank 1981[a]	Company	Chemical sales 1982 ($ millions)	Change from 1981	Chemical sales as % of total sales	Industry classification	Chemical operating profits[b]	Change from 1981	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets	Chemical assets % of total assets	Operating return on chemical assets[d]
51	59	**Esmark**[e]	$630[f]	−3.0%	18.6%	Food	$ 23	−37.9%	12.6%	3.7%	$370	21.0%	6.2%
52	47	**Georgia-Pacific**	628	−14.9	11.6	Wood products	75	−49.7	31.9	11.9	1025	24.7	7.3
53	52	**Borg-Warner**	613	−7.7	19.2	Auto equipment	52	−15.4	22.8	8.5	297	17.7	17.5
54	54	**Pennwalt**	581	−9.4	61.0	Basic chemicals	46	−36.9	61.7	7.9	438	68.2	10.5
55	66	**Standard Oil (Ohio)**	554	12.8	4.1	Petroleum	−23	def	def	def	534	3.3	def
56	50	**Koppers**	535[f]	−21.1	33.8	Diversified	16	−64.1	25.4	2.9	327	29.7	4.7
57	47	**Sun Co.**	516	−30.8	3.1	Petroleum	na	na	na	na	na	na	na
58	56	**Uniroyal**	516	−10.0	26.2	Rubber products	42	−46.8	38.1	8.1	425	36.6	9.9
59	64	**Witco Chemical**	513	0.5	39.3	Specialty chemicals	39	−19.2	34.0	7.5	241	36.4	16.0
60	58	**Badische**	501	−11.0	100.0	Basic chemicals	−8	def	def	def	483	100.0	def
61	61	**Aluminum Co. of America**	493[f]	−5.7	10.7	Nonferrous metals	na	na	na	na	na	na	na
62	62	**Kerr-McGee**	488	−10.0	12.9	Petroleum	−10	def	def	def	656	18.1	def
63	57	**NL Industries**	477	−15.6	21.5	Petroleum services	61	−21.4	21.4	12.8	307	13.4	19.9
64	65	**Airco**	473	−5.4	41.7	Basic chemicals	na	na	na	na	na	na	na
65	66	**Cabot**[g]	471	−4.1	31.0	Specialty metals	62	−4.7	30.1	13.2	264	20.0	23.5
66	55	**El Paso**	468	−16.8	10.7	Natural gas	−102	def	def	def	331	7.9	def
67	70	**National Starch**	467	3.8	67.5	Specialty chemicals	na	na	na	na	na	na	na
68	69	**International Flavors**	448	−0.7	100.0	Specialty chemicals	104	2.0	100.0	23.2	432	100.0	24.1
69	60	**Freeport-McMoRan**	435	−21.4	58.2	Agricultural chemicals	94	−36.6	130.6	21.6	282	17.0	33.3
70	74	**Polysar**	432	9.4	100.0	Basic chemicals	na	na	na	na	na	na	na
71	71	**Beatrice Foods**	419	−6.1	4.6	Food	9	−85.7	1.3	2.1	na	na	na
72	72	**Pfizer**	391	−7.2	11.3	Drugs	−1	def	def	def	421	11.2	def
73	77	**Liquid Air**	371	13.4	82.6	Basic chemicals	48	5.1	99.4	12.9	455	84.8	10.5
74	75	**Internorth**	341	−7.6	8.2	Natural gas	2	−91.1	1.0	0.6	na	na	na
75	—	**Henkel**	475	nc	100.0	Specialty chemicals	na	na	na	na	na	na	na
76	85	**H. B. Fuller**[h]	332	0.9	100.0	Specialty chemicals	25	−18.9	100.0	7.5	207	100.0	12.1
77	73	**Mississippi Chemical**[i]	326	−4.6	100.0	Farm cooperative	25	−67.2	100.0	7.7	375	100.0	6.7
78	78	**GAF**	311	−4.6	49.8	Specialty chemicals	50	−11.5	210.5	16.1	196	41.9	25.5
79	88	**Tyler**	302	9.0	34.6	Diversified chemicals	12	−49.8	23.0	3.9	162	35.0	7.4
80	83	**Rhône-Poulenc**	300	0	100.0	Specialty chemicals	na	na	na	na	na	na	na
81	89	**Big Three Industries**	283	6.9	36.9	Petroleum services	80	1.1	47.5	28.1	489	46.3	16.4
82	93	**Houston Natural Gas**[j]	278	12.3	8.7	Natural gas	32	17.5	8.5	11.5	398	17.0	8.0
83	91	**Petrolite**[e]	275	5.6	90.9	Specialty chemicals	48	9.9	91.0	17.5	161	80.3	29.8
84	80	**Terra Chemicals**	273	−13.9	100.0	Agricultural chemicals	na	na	na	na	na	na	na
85	79	**Upjohn**	268	−17.3	14.7	Drugs	−35	def	def	def	183	9.1	def
86	84	**Vulcan Materials**	263	−12.0	36.5	Nonmetallic minerals	44	−37.2	49.5	16.7	na	na	na
87	88	**Emhart**	253	−6.2	14.8	Machinery	23	−13.4	12.7	9.1	105	11.5	22.0
88	76	**American Petrofina**	252	−24.9	11.2	Petroleum	−7	def	def	def	207	19.1	def
89	92	**Soltex**	250	0	100.0	Basic chemicals	na	na	na	na	na	na	na
90	90	**SCM**[i]	249[f]	−5.5	13.2	Paint	22	−28.2	26.8	9.0	273	24.3	8.2
91	95	**Engelhard**	248[f]	3.4	12.3	Specialty metals	49	4.0	57.2	19.8	238	31.5	20.6
92	—	**Chemed**	233	−1.3	93.6	Specialty chemicals	32	4.3	91.3	13.5	105	63.3	29.9
93	86	**Martin Marietta**	222	−19.7	6.3	Aerospace	19	−60.1	11.9	8.6	239	9.3	7.9
94	97	**Loctite**	216	1.2	100.0	Specialty chemicals	26	99.8	100.0	12.0	200	100.0	13.0
95	96	**Beker Industries**	210	1.6	100.0	Agricultural chemicals	−9	def	def	def	304	100.0	def
96	98	**Stepan Chemical**	208	1.4	100.0	Specialty chemicals	13	−16.6	100.0	6.0	163	100.0	7.7
97	—	**Ferro**	205[f]	−13.3	34.5	Specialty materials	8	−42.9	22.7	4.1	114	32.7	7.4
98	99	**Getty**	202	−1.0	1.6	Petroleum	1	−92.9	0.1	0.5	na	na	na
99	100	**Agway**	194	−3.0	5.1	Farm cooperative	na	na	na	na	na	na	na
100	—	**Great Lakes Chemical**	168	12.9	100.0	Specialty chemicals	29	4.7	100.0	17.3	202	100.0	14.4

a Revised. b Sales minus administrative expense and cost of selling. c Operating profit as a percentage of chemical sales. d Operating profit as a percentage of identifiable chemical assets. e Fiscal year ended Oct. 31, 1982. f Chemical sales include significant amounts of nonchemical products. g Fiscal year ended Sept. 30, 1982. h Fiscal year ended Nov. 30, 1982. i Fiscal year ended June 30, 1982. j Fiscal year ended July 31, 1982. na = not available. nc = not comparable with previous year's data. def = deficit.

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The list of companies ranked for 1982 has changed a little from the 1981 group. Three companies—Nalco Chemical, Merck, and Kaiser Aluminum & Chemical—graduated from the Second 50 to the Top 50 listing of chemical producers in 1982. Meanwhile, Georgia-Pacific and Sun Co., which had been on the Top 50 list in 1981, have fallen back to the Second 50.

One other company, Thiokol, which had been on the Second 50 in previous years, is not on the list for 1982. Thiokol was merged into Morton Norwich during the year, creating Morton-Thiokol. Because of the timing of the merger, total chemical sales figures for the combined company are not available; therefore it was excluded this year. Its sales are undoubtedly high enough to make the Second 50. Next year, when its accounting is resolved, it almost certainly will be back on the list.

There are four new companies included this time that were not on the 1981 list. Henkel is number 75 this year and surely would have qualified in previous years had its chemical sales figures been available.

Chemed, which in previous years had not been included because it was owned largely by W. R. Grace, has broken free of that association and is now ranked 92nd among U.S. chemical producers. Two others—Ferro, ranked 97th, and Great Lakes Chemical, number 100—also are new to the list this year. □

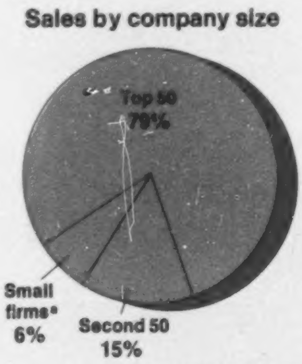
The chemical industry in 1982

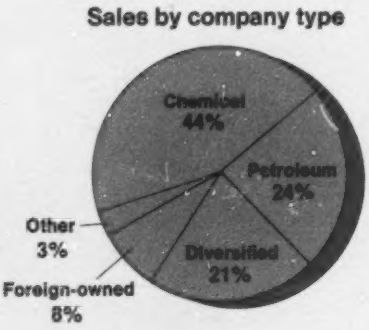
The U.S. chemical industry followed the economy downward last year as chemical sales in the U.S. dropped about 10% from 1981 to $128 billion.

The companies that sold these chemicals include not only C&EN's lists of Top 50 and Second 50 chemical producers but companies that are too small to be included in the listings, and companies that do not report, or inadequately report, their chemical sales. A number of foreign-owned and U.S. companies fall into the last category.

Of the $128 billion in sales by U.S. companies and by foreign-owned companies in the U.S. last year, the Top 50 accounted for a little more than $101 billion, or about 79%. The Second 50 companies sold about $18.6 billion worth of chemicals, or about 15%. The remaining 6% of sales was by firms too small to make the list and companies that do not reveal chemical sales.

By company type, of the $128 million in chemical sales, 44% was by chemical companies. Petroleum and natural gas producers accounted for about 24% of chemical sales. And diversified companies made up about 21%. This group includes companies, though not broadly diversified, that have the majority of their sales in operations other than chemicals or petroleum. Foreign-owned companies accounted for about 8% of chemical sales. Companies that did not disclose their chemical sales made up an estimated 3% of the total.





Total 1982 U.S. chemical sales = $128 billion

a Also includes companies not disclosing chemical sales.

Leaders among the Second 50 in profits, assets, and profitability

Rank		Operating profit ($ millions)		Operating profit margin[a]		Chemical assets ($ millions)		Return on chemical assets[b]
1	International Flavors	$104	Big Three Industries	28.1%	Georgia-Pacific	$1025	Freeport-McMoRan	33.3%
2	Freeport-McMoRan	94	International Flavors	23.2	Kerr-McGee	656	Chemed	29.9
3	Big Three Industries	80	Freeport-McMoRan	21.6	Standard Oil (Ohio)	534	Petrolite	29.8
4	Georgia-Pacific	75	Engelhard	19.8	Big Three Industries	489	GAF	25.5
5	Cabot	62	Petrolite	17.5	Badische	483	International Minerals	24.1
6	NL Industries	61	Great Lakes Chemical	17.3	Liquid Air	455	Cabot	23.5
7	Borg-Warner	52	Vulcan Materials	16.7	Pennwalt	438	Emhart	22.0
8	GAF	50	GAF	16.1	International Flavors	432	Engelhard	20.6
9	Engelhard	49	Chemed	13.5	Uniroyal	425	NL Industries	19.9
10	Liquid Air	48	Cabot	13.2	Pfizer	421	Borg-Warner	17.5
11	Petrolite	48	Liquid Air	12.9	Houston Natural Gas	398	Big Three Industries	16.4
12	Pennwalt	46	NL Industries	12.8	Mississippi Chemical	375	Witco Chemical	16.0
13	Vulcan Materials	44	Loctite	12.0	Esmark	370	Great Lakes Chemical	14.4
14	Uniroyal	42	Georgia-Pacific	11.9	El Paso	331	Loctite	13.0
15	Witco Chemical	39	Houston Natural Gas	11.5	Koppers	327	H. B. Fuller	12.1

a Chemical operating profit as a percentage of chemical sales. b Chemical operating profit as a percentage of identifiable chemical assets.

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Research at EPA: A Crisis of Bad Morale, Unhappy History

Funding cutbacks, lack of permanent director produce drift at agency R&D office; new plan offers some hope, but problems remain

Wil Lepkowski, C&EN Washington

Last week the Senate began the process of confirming William D. Ruckelshaus as fifth administrator of the 12-year-old Environmental Protection Agency. Ruckelshaus will have no trouble getting through and his first order of priority will be to repair the agency's poor enforcement image.

But sooner or later he will have to focus on the agency's crippled research and development program, which currently is suffering from enormous cutbacks and, for more than a year, from no permanent leadership.

The scientific community is concerned. National Academy of Sciences president Frank Press told academy members at their annual meeting a few days ago that EPA "research activities continue to be devastated at a time when more, not less, science is needed for regulatory decision making." Press also criticized the Administration for insisting on ideological "purity" in making appointments to EPA's scientific advisory boards (see page 49).

The Reagan Administration is asking $208 million for fiscal 1984 for EPA's research and development effort, down 14% from 1983 and 38% from its 1982 funding of $336 million. Over the past two years, EPA's research staff has been cut 40%.

EPA's research priorities for the future

Acid rain. A comprehensive atmospheric field study to be started, dry deposit monitoring accelerated, and watershed research studies expanded. Continuing research on limestone injection, multistage burner control technology.

Hazardous waste. Postclosure monitoring of land disposal facilities, screening protocols for hazardous wastes, support for research backup for dumping permits.

Superfund research. Support for engineering activities ceases, shifts to monitoring and environmental effects research. Money for this from Hazardous Substance Response Trust Fund supported by taxes on oil and chemical industries.

Drinking water. Risk assessment, health research, monitoring. Primary drinking water regulations still being revised.

Air. Comprehensive health risk assessments, monitoring methods for sampling and analyzing noncriteria organic pollutants, air quality dispersion models.

Water. Ocean dumping and control requirements. Innovative and alternative municipal treatment technologies, efficient sludge management techniques. Industrial wastewater research will be reduced, reflecting completion of the effluent guidelines effort, and will be refocused to support the wastewater permit program.

Toxic substances. Development of health risk assessment models. Major monitoring study completed; engineering technical support for review of chemicals completed.

During that time, all extramural grants and cooperative agreements in pesticide research were eliminated. In-house epidemiology work was ended. Lead and benzene regulations were relaxed. EPA development work on air and water pollution control technology was ordered stopped, along with research programs on the Great Lakes, diesel emissions, nonpoint source pollution, and nonionizing radiation.

Scientists sympathetic to environmental control were weeded out of the agency's top jobs and advisory roles. The Interagency Regulatory Liaison Groups, by which scientists in, say, the Food & Drug Administration or Department of Agriculture could compare notes with EPA's scientists on common toxic chemicals, also were dissolved. EPA pulled out its support for the National Toxicological Research Center in Pine Bluff, Ark.

But most damaging, in the view of Richard M. Dowd, policy analyst at Environmental Research & Technology Inc., was former EPA Administrator Anne Burford's undermining of scientific integrity in the agency itself. At EPA, science must be tied to regulation but almost never is. But EPA also has the responsibility for looking further ahead toward future problems, "and Burford acted as if she didn't want to hear about them," Dowd says. "Whether Ruckelshaus is successful in repairing the damage is still problematical since he will be serving the same Administration." Comments one EPA R&D staffer: "When you are dealing with politics, science takes a back seat."

In the face of all this, problems continue to mount, if not in size, then in subtlety.

"We are in the early stages of a total reorientation of what we perceive to be the most important environmental problems," J. Clarence Davies, executive vice president of the Conservation Foundation, declared before the House Science & Technology Committee two weeks ago, "and we do not have the scientific information needed to cope with this realization.

"Until recently," added Davies, "we thought that the effects of pollutants were limited primarily to acutely toxic effects on humans and wildlife. We now realize that chronic health effects probably are more important than acute effects and that effects may take decades or even centuries to be perceived. All of the boundaries of time, space, number of pollutants, type of effect, and media that defined environmental problems 10 years ago are no longer valid."

Research always has been an organizational nightmare at EPA. When the agency was established 12 years ago, however, the mood was upbeat. For the first time, an agency was established that could put into practice what many scientific advisory groups had been saying for years: that the environment should be seen as an entirety, unbounded by imaginary lines among the air, water, ground, and living things. With such a holistic perspective, a truly logical, scientifically based assault could be made on society's contamination of Earth.

Under Stanley M. Greenfield, former assistant administrator, research and monitoring, at EPA, a research plan was devised and an organization set up. But by 1975 the whole thing fell apart. The environment may not have boundaries, but bureaucracies do. The air, water, and ground were dubbed "media" and regulatory divisions were established with high, impermeable walls separating them. Greenfield had hoped to devise a research program based on ideas coming up from his researchers. However, EPA was mainly a regulatory agency and the ideas of scientists and the regulators they were supposed to serve never meshed.

C&EN staff photo

Riordan: implementing the latest reorganization plan for R&D office

Walls, in fact, sprang up everywhere. Communication between EPA's engineers and scientists, scientists and legal staff, and EPA scientists and the industries being regulated was terrible. The regulatory staff often was unaware of research at the agency that could help it in its work. The research staff was often impatient with legal fine points, the enforcers with scientific nitpicking. Scientists often declined to pursue research the regulators felt was needed. Industry scientists for their part looked on EPA's regulators as overzealous, overpaid, mediocre boobs. And no one needed to be told with what contempt environmental scientists regarded the industrial ethic.

Things weren't going so well among the researchers, either. Laboratory directors more often competed than cooperated with one another on common projects or regulatory dilemmas. Although they needed to talk to agree on research agendas, they mostly couldn't. And so they didn't. It quickly became clear that good science would not, and probably could not, make for the kind of decisive EPA which, for different reasons, the public and industry could really trust. Research wasn't the same as monitoring, which wasn't the same as enforcement, which wasn't the same as regulation. And as for anticipating future environmental problems, EPA never made any pretense of doing that and still doesn't.

"EPA just never solved the problem of differentiating between information for regulation and information for understanding," says an environmental analyst on Capitol Hill. "The latter is easy; the former is much tougher."

Even now, EPA scientists can't say whether anyone at Love Canal physically suffered from toxic ex-

Since fiscal 1981, only acid rain research funding has increased at EPA

Research funding, $ thousands	1981[a]	1982[a]	1983[b]	1984[c]
Air	$ 67,494	$ 54,402	$ 59,380	$ 51,191
Water quality	62,881	53,529	30,589	19,250
Drinking water	26,345	30,913	23,323	20,900
Hazardous waste	29,643	29,246	32,952	27,389
Pesticides	10,604	7,112	6,521	6,063
Radiation	3,167	2,545	1,726	233
Interdisciplinary	6,385	6,558	6,951	18,144
Toxic substances	35,518	34,146	27,206	23,769
Energy	104,939	31,348	25,001	23,530
Control technology	55,243	12,821	9,633	7,126
Health effects	15,893	2,645	2,389	2,367
Ecological effects	22,632	6,511	450	0
Monitoring systems	3,135	0	0	0
Technical information	875	178	0	0
Acid rain	7,161	9,193	12,529	14,038
Management/support	8,576	7,931	8,662	3,660
Superfund	0	13,813	6,336	6,381
TOTAL	**$355,552**	**$271,543**	**$223,647**	**$205,510**

Note: Fiscal years. a Actual funding. b Estimate. c Funding request.

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posure, a problem that isn't helped when its key office of health is run not by an epidemiologist but by a physicist from the aerospace community. And as for determining the harm to lakes and ponds caused by acid rain, scientists remain unable to agree on general principles for extrapolating measurements taken from small areas to larger regions.

As a result, EPA's R&D staff, involved with 2000 separate research projects on 60 separate issues, is deeply troubled. Although it has undergone only three reorganizations since the agency's founding, it has been reshuffled constantly in response to criticism for lacking focus and foresight.

There's no question that EPA needs help. And no one knows that more than EPA's acting R&D chief Courtney Riordan. Although his permanent job is director of the agency's Office of Monitoring Systems & Quality Assurance, Riordan has been acting director of the Office of R&D for more than a year and is in the process of implementing the latest reorganization plan for that office. The new scheme would give its laboratory directors around the country more control of research program planning and set up what appears to be a complex interplay of offices.

Lead or "master" laboratories for health, engineering, biology (or ecosystems), transport and fate of pollutants, and environmental measurement (or monitoring) would be set up. Thus, certain laboratory directors would become "superdirectors" of research and no one knows the consequences of that on morale. And the plan also would set up an office of research planning for the categories of air, noise, and radiation; water; solid waste and emergency response; pesticides and toxic substances; and technical assistance and liaison. It would form the link between EPA research and regulation. "This new plan," comments one office head, "is not only too ridiculous to understand, but it seems to set up the same kinds of problems we've been trying to get rid of."

That may be overcritical. Two years ago, EPA began establishing research committees composed of regulators and research administrators in Washington. The goal was to bring about that long-missing marriage between what were really two separate EPAs. The committees now number 12 and include drinking water, pesticides, particulate and gaseous air pollution, oxidants, testing and assessment, and water quality, among others.

Davies: chronic health effects are more important than acute

Now the goal is to bring laboratory directors more directly into that process. And it is seen as a definite plus in an agency whose laboratories more often resemble provincial outposts than national centers. Riordan knows what the problems are and says the plan, although defensible, needs to go even further. "What's still missing is the synthesis," he says. "I think the reorganization will solve problems at the planning level. But we'll also need integration at the project level."

That could be the toughest job. Laboratory directors and scientists don't do a good job at crossing disciplines and working jointly on common projects. A chemist working on atmospheric transformations of arsenic, for example, has trouble communicating with an ecologist who wants to know how it moves through the ecosystem.

Moreover, the plan has been cooking for much too long anyway. "Any expert on organizational development will tell you that—especially in a bureaucracy—when you reorganize you should do it fast. The longer it drags out, the less likely it will be accepted."

EPA's research has been criticized on many levels of logic over the years, but the criticism most common is that the agency has never made a priority of gearing research to foresee crises. "You'll see EPA respond to a crisis by buying an entire town," says a Congressional staffer who follows EPA's research, "but they don't usually do the research that would allow us to anticipate problems. And that's been true for years."

One big problem is that EPA makes scant attempt to seek data from agencies that do ecological research. For example, USDA does research on the beneficial aspects of pesticide development. One would think USDA researchers would be turning up interesting findings on the path of pesticides through the ecosystem. If they do, EPA doesn't try to find out. According to one scientist in EPA's pesticides division, there is no coordination between the two agencies. Too often the agency is forced to respond to crises like Times Beach or Love Canal. One gets the picture of an R&D office that is being jerked around so much that it loses a sense of identity.

Riordan knows that the core of the problem lies in the budget process. "There," he says, "you are forced to put priorities in areas you get yelled at for not doing. So what gets lower priority are important things like hazardous air pollutants, or indoor air pollution, or acid rain, or special chemicals like furans or PCBs, or longer-term research on basic atmospheric processes that create pollutants. So the agency doesn't get any better at developing the information base it will need for making decisions on hazardous chemicals. In sulfur dioxide particulates, decisions have been made off data that haven't changed for 20 years."

The answer? One Congressional aide says leadership obviously is needed at the White House level. There is need for a strong advocate of the R&D office. Presidential Science Adviser George A. Keyworth II, a physicist, is on record as having scant respect for the work of environmental scientists, so he is far from the advocate EPA needs.

"Why don't people, really good people, want to take that job as head of research at EPA?" asks the aide. "It's probably because it sits too far down the peer ladder. Would you want it on your résumé that you were head of EPA's office of research and development? I don't think it would impress anyone."

But it also makes sense to say that whoever can take over that office and give environmental research the prestige it needs will go down in science history as an administrator with the wisdom of Solomon. □

Patent office plans to automate fully by 1990

"No more paper" could well be the new slogan of the Patent & Trademark Office (PTO). It is undertaking an ambitious, multimillion-dollar effort to fully automate its operations by 1990, and Chemical Abstracts Service, a division of the American Chemical Society, may play a role in that effort.

PTO processes and examines more than 100,000 patent applications annually, comparing the applications' subject matter to a large body—24 million documents—of technological information to determine whether the inventions are new and not obvious to someone knowledgeable in that field. But because the files are all paper, problems occur. According to PTO, up to 7% of the file is missing at any time, threatening the quality of patent grants. Processing paper applications requires moving large amounts of paper frequently and matching some 20,000 pieces of mail daily with corresponding files distributed throughout PTO offices.

But the future, as PTO sees it, is electronic. That means that from the moment a patent application arrives at the patent office until a decision is made to grant or not grant a patent, every step will be handled by a computer. Examiners will do the necessary comparisons to determine if an invention is patentable at electronic work stations, using available commercial, as well as PTO's own, databases. Approved applications will be extracted automatically from the database and prepared for photocomposition and printing. Maintenance fees also will be handled through the system.

But for the system to operate, an examiner, for example, must be able to search for and retrieve the particular piece of information that is needed. As J. Howard Bryant, administrator for automation at PTO, says, the system is software driven and that is where CAS comes in. Close to 40% of patent searches involve chemistry, and CAS has developed a system to create, store, maintain, and retrieve a large database of chemical structures and text from interactive work stations such as the PTO envisions using.

"Rather than attempt to reinvent that part of the system," Bryant explains, "what we are contemplating doing is awarding a contract for the use of [CAS] software as a base" for the PTO system. He believes that the CAS system is unique and that nobody else has anything comparable to offer. Just to make certain, PTO published an announcement of the contemplated award to CAS in the April 25 issue of *Commerce Business Daily*, making it clear that a contract with CAS would not limit contracts for other commercial databases that might be needed for patent examination.

The announcement says that anybody who does have a search and retrieval system that they think would be comparable to CAS's should notify PTO within 30 days. "If there are no offers of substance, we would propose to go forward with the contract award" to CAS, Bryant says. No cost estimate for the CAS part of the automation effort is available, but Bryant says, "We estimated that over 20 years, the systems' cost, both developmental and operational, including our personnel, would come to about $750 million." The actual cost of getting the system up (above and beyond the benefits PTO will receive during the developmental period) is about $25 million. But as he points out, it costs PTO $5 million a year just to store the paper files it has now. □

Federal Alert—new regulations

This listing covers noteworthy regulations published in the Federal Register *from March 28 to April 30. Page numbers refer to those issues.*

PROPOSED

Drug Enforcement Agency—Raises fees as much as fivefold for registration of controlled substances by manufacturers and distributors; comments by June 6 (April 5, page 14640).

Environmental Protection Agency—Proposes and requests comments on variety of regulations to control disposal of hazardous wastes containing chlorinated dioxins, dibenzofurans, and phenols; comments by June 3 (April 4, page 14514).

Lists new emissions standards for radionuclides for variety of sources; comments by May 30 (April 6, page 15076).

Publishes semiannual agenda of expected regulatory actions (April 25, page 18468).

Federal Energy Regulatory Commission—Suggests amendments to eliminate some record-keeping regulations for natural gas and oil pipeline companies; comments by May 23 (March 28, page 12722).

Occupational Safety & Health Administration—Moves to lower eight-hour time-weighted-average exposure of workers to ethylene oxide to 1 ppm from current 50-ppm level; comments by June 17 (April 11, page 17284).

Publishes semiannual agenda of expected regulatory actions (April 25, page 18184).

FINAL

Energy Department—Establishes standard contract for disposal of spent nuclear fuel and/or high-level radioactive waste; effective April 18 (April 18, page 18590).

Environmental Protection Agency—Revises specifications and test procedures for use of continuous emissions monitoring systems to measure opacity; effective March 30 (March 30, page 13022).

Adds additional chemicals to list of substances for which unpublished health and safety studies must be submitted under Toxic Substances Control Act; effective April 29 (March 30, page 13178).

Gives assistant administrator for pesticides and toxic substances authority to approve certain polychlorinated biphenyl disposal facilities that previously required approval of EPA regional administrator; effective April 29 (March 30, page 13181).

Nuclear Regulatory Commission—Gives power plant licensees authority to take reasonable actions that are not strictly permitted under licensing conditions in an emergency situation; effective June 1 (April 1, page 13966).

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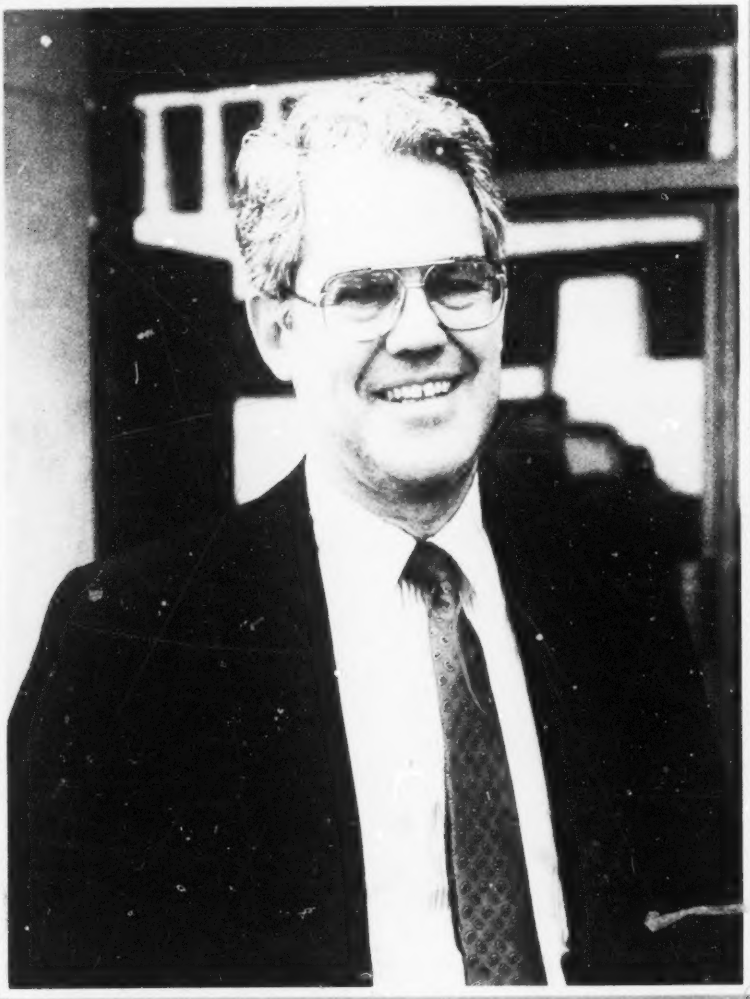
Chemical earnings finally hint a turnaround Page 20

MAY 16, 1983

CHEMICAL & ENGINEERING NEWS



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National Science Foundation

New chief Edward Knapp leads agency back to basics
Page 11

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Cover: Photo by David J. Hanson

CHEMICAL & ENGINEERING
NEWS

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MAY 16, 1983

News of the Week

- Planned production of binary chemical weapons assailed from many sides. Page 6
- Test facility designed to study incineration of hazardous wastes ready to operate. Page 7
- Space shuttle test of device to separate biological materials deemed a success. Page 7
- Firestone will develop and design prototype plant to process guayule rubber in Arizona. Page 7
- PCB levels in human tissue have dropped sharply. Page 8
- Chemical analysis proved the Hitler diaries fakes. Page 8

Business

First-quarter chemical industry earnings continue the year-to-year drop but by smaller amounts than in previous quarters. **Page 20**

International

Combined first-quarter sales of major Canadian chemical firms were higher than in the past two quarters, losses lower. **Page 31**

Government

Congress focuses on fiscal 1984 budget resolution, which allows $8.5 billion for science, space, and technology. **Page 34**

Science

Repression of Soviet refusenik scientists continues under the new regime; chemist Yuri Tarnopolsky is latest victim. **Page 45**

Publication of table of chemical properties is result of 20-year effort to update National Bureau of Standards data. **Page 47**

Guidelines for integrity of research urge universities to establish policies and sanctions to encourage intellectual honesty. **Page 48**

Books

"Women Scientists in America: Struggles and Strategies to 1940" by Margaret W. Rossiter analyzes women's participation in U.S. science, recounting their struggles and victories. **Page 50**

News Focus

Physicist Edward Knapp swings NSF to conservative path as the way to cope with challenges of a high-tech future. Page 11

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Chemical Earnings Still Down, But Not So Much

Profits and sales still fell in first quarter, but there are reasons for some cautious optimism for the rest of the year

William J. Storck, David Webber
C&EN New York

The low point finally has been reached in the U.S. chemical industry's financial turmoil of the past three years.

First-quarter 1983 earnings at major basic chemical companies, as well as chemical-producing oil and diversified firms, continued their year-to-year drop. But the shortfall was much less than in the fourth quarter of 1982. For 1983 as a whole, it now appears as if earnings finally will rebound, perhaps rising 15% over 1982, on a sales increase of roughly 8%.

However, it's still not time to celebrate. The optimism on earnings prospects that prevailed toward the end of 1982 has been somewhat tempered by the realities of the first quarter this year. Many chemical executives are saying that financial results will not brighten a lot until later in the year. This would not be that unusual, since chemical earnings normally lag in economic recoveries.

There are a number of reasons for the still-poor earnings of the first quarter. Most important, demand was not yet healthy. Many end-use markets for chemicals turned up but not to levels boosting profits. Still, the quarter's business volume improved considerably as it progressed, so there is hope for better results in the second quarter and the year as a whole.

The one market area that still hurt the chemical industry badly in the first quarter—and is not likely to improve for some time—is agriculture. The government's payment-in-kind (PIK) program is reducing crop plantings and hence sales of agricultural chemicals.

Overall, though production in chemicals and allied products, according to Federal Reserve Board data, was still off 1.4% in the first quarter from the same period in 1982, this is the smallest annual decrease since the fourth quarter of 1981. And although the government's producer price index for chemicals and allied products is still 1.4% below a year ago, indications are that prices are firming. For instance, some of the recently announced price increases have been successful, according to chemical executives.

For the first quarter this year, combined sales at 30 leading basic chemical companies surveyed by C&EN fell about 6% to $16.3 billion from first-quarter 1982. At the same time, earnings for this group of companies dropped 27% to $627 million. (This year, C&EN has narrowed its group of leading basic chemical companies from 40 to 30 to provide more timely and consistent quarterly data.)

Although a 27% fall in earnings is rough, it is the smallest decrease since the first quarter of 1982. And actual earnings in the first quarter this year were up 39% from the fourth quarter in 1982. True, first-quarter earnings tend to increase seasonally 10 to 15% from the fourth quarter, but the current increase is far above that and hence signals a real gain. In the previous two years, the corresponding earnings increase was 7% in 1982 and 12% in 1981. The current increase is all the more wel-

Chemical industry leaders for first quarter

Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1982		$ Millions	Rank 1982		Earnings as % of sales	Rank 1982
1	Dow Chemical	$2538.0	1	Monsanto	$101.0	1	International Flavors	15.1%	1
2	Union Carbide	2190.8	2	Dow Chemical	54.0	2	Freeport-McMoRan	10.3	2
3	Monsanto	1488.0	3	PPG Industries	43.8	15	Nalco Chemical	9.5	9
4	W. R. Grace	1351.9	4	Union Carbide	41.7	3	Lubrizol	9.2	8
5	PPG Industries	856.7	7	Rohm & Haas	33.7	16	Petrolite	8.8	4
6	American Cyanamid	825.3	6	W. R. Grace	32.9	5	Loctite	8.6	12
7	Celanese	766.0	5	Air Products	24.6	9	Rohm & Haas	7.3	20
8	Hercules	602.0	8	Hercules	24.4	11	Monsanto	6.8	6
9	National Distillers	587.1	12	Morton-Thiokol	23.4	—	Air Products	5.9	10
10	Olin	473.1	10	Olin	22.6	10	International Minerals	5.7	11

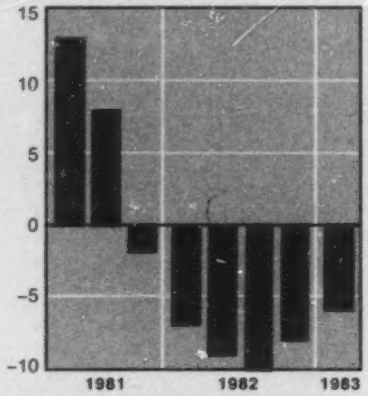
a After taxes. **Note:** For 30 companies listed on page 22.

Chemical industry 1983 first-quarter results

- Sales fell 6%
- Earnings dropped 27%
- Profit margins sank
- Production slid 1.4%
- Prices declined

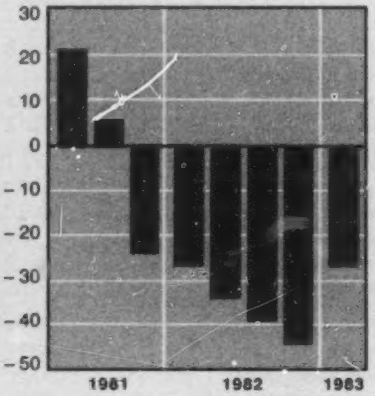
Sales

% change from year-earlier quarter



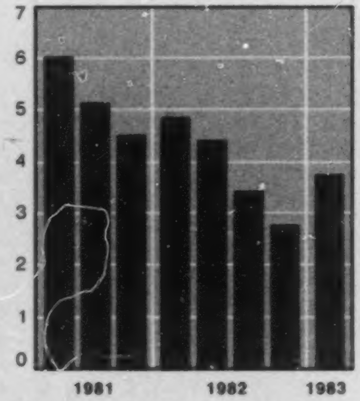
Earnings

% change from year-earlier quarter



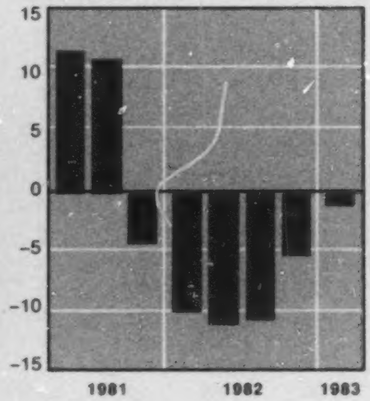
Profit margins

After-tax earnings as % of sales



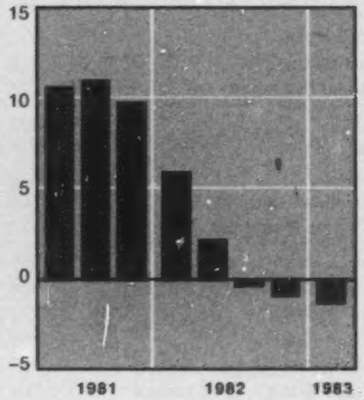
Production

% change from year-earlier quarter



Prices

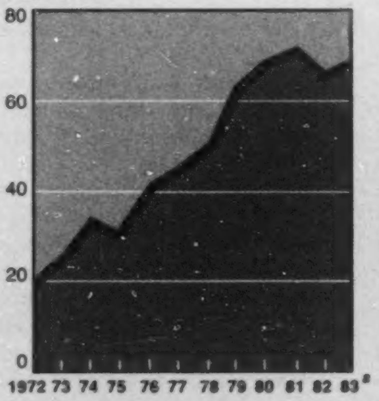
% change from year-earlier quarter



Sales in 1983 will rise 8%; earnings will increase 15%, driving chemical profitability up

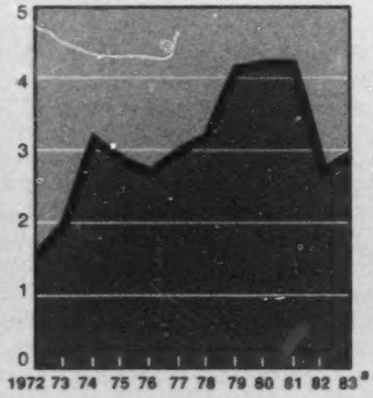
Annual sales

$ Billions



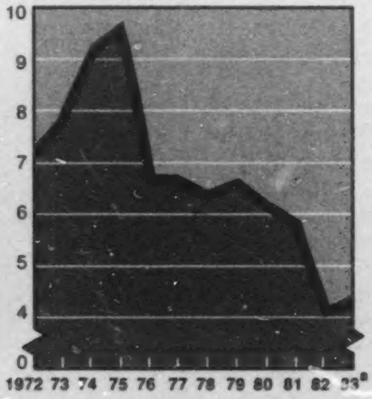
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



a C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on the combined performance of the 30 leading chemical companies listed on page 22.

Profit margins still fall at most major chemical companies

	FIRST-QUARTER 1983						12-MONTH RUNNING DATA			
	Sales	Earnings	Change from 1982		Profit margin[a]		Change from 1982		Profit margin[a]	
	($ millions)		Sales	Earnings	1983	1982	Sales	Earnings	1983	1982
Air Products	$ 414.0	$ 24.6	4%	−16%	5.9%	7.3%	2%	−14%	6.5%	7.7%
American Cyanamid[d]	825.3	21.4	−2	−25	2.6	3.4	−5	−37	3.5	5.2
Celanese	766.0	6.0	−10	−70	0.8	2.4	−20	def	def	3.5
Chemed	60.6	3.7	1	−29	6.1	8.7	−1	−40	6.1	10.1
Crompton & Knowles	54.4	1.2	1	50	2.2	1.5	−10	−30	2.5	3.2
Dow Chemical[e]	2,538.0	54.0	−9	−44	2.1	3.5	−12	−66	1.7	4.5
Ethyl	395.9	20.2	−2	18	5.1	4.3	−7	11	6.0	5.0
First Mississippi	47.0	1.7	−9	−61	3.6	8.5	−40	−43	6.5	6.9
Freeport-McMoRan	204.2	21.1	5	−20	10.3	13.6	−6	−33	12.2	16.9
H. B. Fuller	95.5	1.9	31	75	1.9	1.5	10	−20	2.7	3.6
W. R. Grace[f]	1,351.9	32.9	−8	−58	2.4	5.4	−7	−35	3.5	5.0
Hercules	602.0	24.4	−6	11	4.1	3.4	−10	−29	3.9	5.0
International Flavors	121.5	18.4	2	2	15.1	15.2	2	0	14.1	14.2
International Minerals	371.6	21.2	−4	−17	5.7	6.2	−19	−41	5.0	6.7
Loctite	55.4	4.8	1	46	8.6	6.0	−2	9	7.1	6.3
Lubrizol	184.5	16.7	−6	7	9.2	8.1	−7	−45	6.1	10.4
Monsanto	1,488.0	101.0	−14	−31	6.8	8.5	−10	−14	4.9	5.1
Morton-Thiokol[g]	445.0	23.4	—	—	5.3	4.4	—	—	—	—
Nalco Chemical	159.5	15.2	1	21	9.5	7.9	−6	−17	9.9	11.6
National Distillers[h]	587.1	15.0	26	−12	2.6	3.7	−2	−47	3.6	6.6
Olin[i]	473.1	22.6	−5	3	4.8	4.4	−9	−27	3.5	4.4
Pennwalt	237.9	6.3	−4	0	2.6	2.6	−6	−30	2.6	3.5
Petrolite	71.9	6.3	−13	−26	8.8	10.3	−5	−8	9.3	9.5
PPG Industries[j]	856.7	43.8	14	166	5.1	2.2	2	0	5.1	5.2
Reichhold Chemicals	178.5	4.2	−14	27	2.4	1.6	−16	−40	1.3	1.8
Rohm & Haas	462.0	33.7	−3	111	7.3	3.4	−4	9	5.1	4.5
Stauffer Chemical	364.0	18.8	−42	−77	5.2	13.0	−22	−62	4.0	8.3
Union Carbide	2,190.8	41.7	−5	−54	1.9	3.9	−9	−59	2.8	6.2
Williams Cos.[k]	369.2	8.6	−6	46	2.3	1.5	−11	−44	1.9	3.1
Witco Chemical[l]	323.0	10.7	−3	118	3.3	1.5	−1	−2	2.8	2.8
Top 15 largest companies[m,n]	**$13,765.0**	**$473.3**	**−5%**	**−25%**	**3.4%**	**4.3%**	**−14%**	**−44%**	**3.1%**	**4.7%**
Second 15 companies[m]	**$ 2,529.5**	**$153.4**	**−11%**	**−31%**	**6.1%**	**7.8%**	**−11%**	**−30%**	**5.1%**	**6.5%**
TOTAL[n]	**$16,294.5**	**$626.7**	**−6%**	**−27%**	**3.8%**	**4.9%**	**−13%**	**−41%**	**3.4%**	**5.0%**

a After-tax income as a percentage of sales. b Fully diluted before nonrecurring and extraordinary items. c As of April 29. d Excludes nonrecurring gains of $5.8 million in first-quarter 1983 and $9.6 million in first-quarter 1982. e Excludes nonrecurring gains of $15 million in first-quarter 1983 and $57 million in first-quarter 1982. f Excludes $65.1 million gain in first-quarter 1982. g Since merger of Morton and Thiokol, previous quarterly figures have not been restated, making comparisons with prior data meaningless. h Excludes $11.3 million nonrecurring gain in first-quarter 1982. i Results for 1983 include Olin's share of sales and earnings from Philip A. Hunt Chemical. j Excludes nonrecurring gain of $7.6 million in first-quarter 1982.

come after three straight quarter-to-quarter earnings declines in 1982.

Profit margins also increased from the fourth quarter but were still lower than in the first quarter last year. At the 30 companies surveyed, profit margins averaged 3.8% in the first quarter and 4.9% in the same period last year.

Within these overall results, the 15 largest companies on the list outperformed the second 15 in terms of sales and earnings. However, profitability for the smaller companies remained higher.

For the 15 larger firms, sales dropped 5% from first-quarter 1982 to $13.8 billion. Earnings at these companies fell an average of 25% to $473 million. At the smaller companies, sales dropped 11% to $2.53 billion, and earnings fell 31% to $153 million. As a result, profit margins at the larger companies fell to 3.4% in the first quarter from 4.3% in first-quarter 1982, and at the smaller companies, profitability fell to 6.1% from 7.8%.

In explaining first-quarter results, some company executives note that raw material cost breaks helped operations. For example, Paul F. Oreffice, Dow Chemical president and chief executive officer, says that a reduction in naphtha prices helped the company's feedstock cost situation.

Companies also noted improved plant utilization rates in the first quarter. At Pennwalt, chairman Edwin E. Tuttle says, "Chemical operating rates are inching upward and although the situation is still far from satisfactory, we are delighted with the improvement that finally seems to be under way." Du Pont noted a gain in capacity utilization to 72% in March from 62% in January.

However, there remains the agricultural chemicals headache. At Monsanto, where farm markets are particularly important, sales of agricultural and nutritional products, STOCK MARKET DATA[c]

Earnings per share[b]		Stock price			Price-earnings ratio	Annual indicated dividend	Dividend yield, % of price
			Recent 12 months				
1st qtr	Full year	April 29	High	Low	April 29		
$0.79	$3.60	$42⅞	$48⅛	$23⅝	12	$0.80	1.9%
0.36	2.38	45½	47½	24⅝	19	1.75	3.8
0.32	−0.90	62⅛	62¼	41¼	—	4.00	6.4
0.43	1.78	36¾	36¾	21⅝	21	1.36	3.7
0.35	1.21	27⅞	28	12⅛	23	1.04	3.7
0.28	1.56	33⅛	33⅛	19⅝	21	1.80	5.4
0.48	2.44	18⅛	20¾	9¼	7	0.85	4.7
0.08	0.65	11	12⅝	6	17	0.24	2.2
0.30	1.32	21¾	23⅝	12¼	16	0.60	2.8
0.40	2.04	32¾	33¾	22¾	16	0.56	1.7
0.67	4.26	44½	45½	28½	10	2.80	6.3
0.54	2.12	36½	36¾	16⅞	17	1.32	3.6
0.50	1.74	28¼	30	17⅝	16	1.04	3.7
0.79	2.70	39½	40⅞	23½	15	2.60	6.6
0.48	1.52	38	40¼	18⅛	25	0.56	1.5
0.43	1.24	20⅞	22¾	14¼	17	1.08	5.2
2.47	7.65	91	94	56⅝	12	4.20	4.6
1.40	—	65¾	66¾	27¾	6	1.60	2.4
0.41	1.64	31	35	18	19	1.12	3.6
0.39	1.86	27¾	28⅛	18⅞	15	2.20	7.9
0.95	2.68	32	32	15½	12	1.20	3.8
0.61	2.37	38⅝	40⅜	21½	16	2.20	5.7
0.53	2.28	28	33¾	27¾	12	1.00	3.6
1.26	5.06	65⅜	65½	29⅛	13	2.36	3.6
0.50	0.89	26⅝	27	10⅛	30	0.48	1.8
2.61	7.19	116½	117½	45½	16	2.80	2.4
0.43	1.24	24⅞	28⅜	17	20	1.44	5.8
0.60	3.61	64½	64½	40⅛	18	3.40	5.3
0.29	1.21	25⅝	24⅞	12⅝	20	1.20	4.9
1.08	3.41	39⅞	40	20⅝	12	1.80	4.5

k Excludes nonrecurring gain of $6.4 million in first-quarter 1983. l Excludes net gain of $3.1 million in first-quarter 1982. m Division between large and small companies is about $365 million in first-quarter 1983. n Per cent change and profit margin averages exclude results of Morton-Thiokol.

largely pesticides, dropped 27% from last year's first quarter to $333 million. Earnings fell 44% to $109 million.

American Cyanamid president George J. Sella Jr. says that pesticide sales were down at Cyanamid because of continuing high distributor inventories and the expectations of lower crop plantings as a result of the PIK program.

One of the worst cases of agricultural chemical blues occurred at Stauffer Chemical. Total company sales were off a thumping 42% and earnings down 77% from a year before, almost all because of farm market trouble. Ordinarily, Stauffer's sales peak for agricultural chemicals is in the first quarter. However, 1983 U.S. sales of pesticides were $60 million, down a full 80% from first-quarter 1982. If it had not been for this drop, Stauffer's total sales would have been down just 6%. Stauffer says the pesticide collapse was due to an estimated one-third reduction in planted corn acreage and above-normal pesticide inventory carryovers. In addition, the company shifted $72 million in pesticide sales to the fourth quarter of 1982 from this year's first quarter.

Poor performance by fertilizer and other agricultural chemicals also cut into earnings of nonoil, diversified

Oil companies' chemicals barely break even

Oil and gas companies, glumly watching their profit margins shrivel as world petroleum prices fell, got no solace at all from their petrochemical operations in the first quarter of 1983. Seven leading oil producers providing after-tax data earned a grand total of just $900,000 on chemicals in the first quarter of this year, down 91.5% from $10.6 million a year earlier.

For the most part, producers blame poor demand, overcapacity, and consequent low prices for their depressed petrochemical earnings. Although Exxon, Shell Oil, and others made money, Gulf Oil, with another terrible quarter, had a deficit large enough to offset the gains of its profitable competitors in overall figures.

Pretax reports from other oil companies show little better. Atlantic Richfield lost $3 million on chemicals, and Standard Oil (Ohio) lost $12 million. Other firms did not break out their chemical income, but Phillips Petroleum, El Paso, Internorth, and American Petrofina tersely note that chemical operations were either unprofitable or failed to improve over 1982.

On the positive side, first-quarter chemical results were a step up from fourth-quarter 1982, when all but Exxon recorded deficits. Still, most firms remain cautious. Shell, for instance, although expecting considerable improvement over 1982 this year, quickly adds a note of caution. "Chemical price trends are mixed," says president John F. Bookout Jr., "as industry overcapacity pressures continue, and we are now experiencing increases in feedstock costs. Taken together, these factors could dampen the growth in chemical earnings over the balance of the year."

	First-quarter after-tax earnings on chemical operations		
$ Millions	1983	1982	% change
Exxon	$32.0	$27.0	19%
Getty Oil	−1.1	−1.1	def
Gulf Oil	−39.0	−82.0	def
Internorth	0.0	2.7	−100
Mobil	−14.0	13.0	def
Shell Oil	19.0	10.0	90
Standard Oil (Ind.)[a]	4.0	41.0	−90

a Excludes nonrecurring $14 million gain in first-quarter 1982. def = deficit.

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Oil companies' earnings still suffer, but other firms improve

	% chemical sales	Sales ($ millions)	Earnings[a] ($ millions)	Change from 1982 Sales	Change from 1982 Earnings	Profit margin[b] 1983	Profit margin[b] 1982
OIL AND GAS COMPANIES							
American Petrofina	11%	$ 425.3	$ 0.3	−26%	−98%	0	2.8
Atlantic Richfield	8	6,319.2	330.4	−2	−14	5.2	6.0
El Paso	15	1,222.8	14.3	16	−33	1.1	2.2
Exxon	7	23,705.0	1060.0	−12	13	4.5	3.5
Getty Oil	2	3,005.1	171.8	−4	−4	5.7	2.6
Gulf Oil	7	6,898.0	182.0	−9	−37	2.6	3.8
Internorth	8	1,359.7	102.0	−6	−6	7.5	7.5
Kerr-McGee	13	850.6	23.8	−9	−49	2.8	4.9
Mobil	3	14,300.0	250.0	−13	3	1.8	1.5
Occidental Petroleum[c]	na	4,890.0	9.9	16	−76	0.2	1.0
Phillips Petroleum	15	3,640.0	129.0	−4	−19	3.5	4.2
Shell Oil	17	4,645.0	246.0	−4	−29	5.3	7.1
Standard Oil of California	3	6,995.0	310.0	−30	35	4.4	2.3
Standard Oil (Ind.)[d]	9	7,500.0	399.0	−4	−13	5.3	6.3
Standard Oil (Ohio)	4	2,766.0	387.0	−24	−15	14.0	12.6
Sun Co.	3	3,740.0	90.0	−8	−21	2.4	2.8
Tenneco	7	3,609.0	111.0	−4	−14	3.1	3.4
Texaco[e]	3	10,200.0	319.0	−22	−2	3.1	2.5
Union Oil	11	2,470.0	128.3	0	−24	5.2	6.8
DIVERSIFIED MANUFACTURERS							
Aluminum Co. of America[f]	11	1,142.2	−14.3	−5	def	def	2.0
Allied[g]	23	2,569.0	79.0	−4	0	3.1	3.0
Beatrice Foods[h]	5	2,277.3	79.5	2	7	3.5	3.3
Borden[i]	30	937.3	22.7	1	32	2.5	1.8
Borg-Warner	19	813.5	35.5	10	−2	4.4	4.9
Diamond Shamrock[j]	31	855.4	4.6	8	−84	0.5	3.7
Du Pont	32	8,597.0	203.0	4	−19	2.4	3.0
Eastman Kodak[k]	20	2,129.9	136.8	−5	−25	6.4	8.1
Engelhard	12	611.4	16.2	40	13	2.6	3.2
FMC	37	853.7	31.5	1	−3	3.7	3.9
General Electric	4	6,100.0	425.0	1	13	8.9	8.1
Georgia-Pacific	12	1,419.0	3.1	18	−98	0.2	12.9
B. F. Goodrich[l]	36	734.0	−14.9	1	def	def	def
Kaiser Aluminum[m]	22	586.1	−51.0	−20	def	def	def
Koppers[n]	34	287.5	−12.8	−13	def	def	def
Eli Lilly	27	831.9	136.2	−4	0	16.4	15.8
Merck	21	770.8	113.7	4	4	14.8	14.8
NL Industries	30	386.0	−8.2	−42	def	def	14.1
Northwest Industries	24	419.2	1.4	−53	−99	0.3	11.9
Pfizer[o]	11	910.4	106.9	11	37	11.8	9.5
Procter & Gamble	4	3,131.0	218.0	1	10	7.0	6.4
3M	15	1,703.0	157.0	2	3	9.2	9.1
Tyler[p]	35	212.1	0.8	2	870	0.4	0.0
Uniroyal	30	450.5	3.6	−7	200	0.8	0.2
U.S. Steel	6	3,860.0	−118.0	−23	def	def	0.0
Upjohn	17	484.1	43.1	5	0	8.9	9.4
Vulcan Materials	37	154.6	0	−6	def	def	6.1

a Excludes major nonrecurring gains or charges to earnings. b After-tax income as a percentage of sales. c Excludes nonrecurring gains of $16 million in first-quarter 1983 and $21 million in first-quarter 1982. d Excludes nonrecurring $14 million gain in first-quarter 1982. e Excludes nonrecurring $43 million gain in first-quarter 1982. f Excludes nonrecurring $19.9 million gain in first-quarter 1982. g Results for first-quarter 1982 reflect Bendix consolidation on pro forma basis. Excludes nonrecurring $39.0 million gain in first-quarter 1983. h Results for three months ending Feb. 28, 1983 (fourth quarter of Beatrice's 1983 fiscal year). Excludes nonrecurring $278.0 million charge in fiscal fourth-quarter 1983. i Excludes nonrecurring gains of $17.0 million in first-quarter 1983 and $17.6 million in first-quarter 1982. j Excludes nonrecurring $35.6 million gain in first-quarter 1982. k Excludes nonrecurring charge of $87.4 million in first-quarter 1983. l Excludes nonrecurring gains of $7.1 million in first-quarter 1983 and $1.9 million in first-quarter 1982. m Excludes nonrecurring $22.2 million gain in first-quarter 1983. n Excludes nonrecurring charges of $200,000 in first-quarter 1983 and $400,000 in first-quarter 1982. o Results for first-quarter 1982 restated to reflect acquisition of Valleylab. Excludes nonrecurring gains of $4.3 million in first-quarter 1983 and $11.0 million in first-quarter 1982. p Excludes nonrecurring gain of $800,000 in first-quarter 1983. na = not available. def = deficit.

chemical producers. Companies as varied as Allied, Uniroyal, and Kaiser Aluminum & Chemical (whose total earnings declined in the first quarter) and Eli Lilly (whose earnings rose) branded the agricultural sector a major drain on income. Again, the federal government's payment-in-kind program was the chief culprit. Lilly, for instance, typically noted that the uncertainties created by PIK caused lower sales of Treflan, its dominant herbicide.

Agricultural and other problems conspired to reduce combined earnings of 24 diversified companies with chemical operations 23.9% from first-quarter 1982. Seven of these producers lost money in the first quarter, led by U.S. Steel with a $118 million deficit. And among those recording profits, earnings in many cases were sharply lower than the year before—for example, down 99% at Northwest Industries, 98% at Georgia-Pacific, 84% at Diamond Shamrock, and 25% at Eastman Kodak.

As a result, profit margins for the 24 firms wilted to 3.9% in first-quarter 1983 from an average of 5.6% in first-quarter 1982.

Thanks to lower prices and demand, profits also were off at oil and gas companies with chemical operations, although not so much as at the diversified companies. Combined earnings at 19 oil and gas firms were 17% lower in first-quarter 1983 from first-quarter 1982. Profit margins shrank to an average of 4.1% from 4.4%. Big losers were American Petrofina, El Paso, Gulf Oil, Kerr-McGee, Occidental Petroleum, and Shell Oil. Of the 19 firms, only three—Exxon, Mobil, and Standard Oil of California—had an earnings increase.

Perhaps it's best to think of the direction and not the present position of these producers' financial health. Recovery from these companies' most prolonged economic downturn since the depression wasn't going to happen overnight, and industry executives never thought it would. For the moment, the tilt in performance as the second quarter rolls along is decidedly up. The next batch of corporate financial reports, due in July, should be much better reading. □

Canadian Chemical Firms Optimistic That Slide Is Ending

Combined first-quarter sales of four major chemical firms are higher than in previous two quarters; also, combined losses are less

Optimism, a commodity that was conspicuously missing last year, has returned to the ranks of Canadian chemical executives. It is a mild form of optimism, to be sure, but after 1982's dismal performance, even a small dose is welcome.

Collectively, the four large publicly reporting companies charted by C&EN (C-I-L Inc., Celanese Canada, Du Pont Canada, and Union Carbide Canada) lost $1.1 million (Canadian) in the first quarter of 1983 on sales of $767 million (down 3.3% from the first quarter of 1982).

But collective statistics and first-quarter comparisons don't tell the whole story. Collective sales in the first quarter are higher than in the previous two quarters. And the collective loss of these four companies is less than in the previous three quarters.

Individually, Celanese Canada came storming back in the first quarter in both sales and earnings. Sales, at $94.1 million, were 19% higher than in the first quarter of 1982 and were higher than in any single quarter of last year. Profits jumped a hefty 67% over the like 1982 period to $1.5 million, also better than any of last year's quarters.

Celanese's sales were aided, in large part, by the startup of its huge methanol plant at Edmonton, Alta., and by a shutdown of Ocelot Industries' methanol unit at Kitimat, B.C. However, president and chief executive officer Ernest H. Drew says that other business sectors, especially polyester, polypropylene, and industrial products, also chalked up major sales increases.

Du Pont Canada also managed to improve sales slightly to $254 million, up 2.5% over 1982's first quarter. And the company turned a $1.2 million loss in the first quarter of 1982 into a $1.0 million profit in this year's first period. For Du Pont, Canadian sales were up 6% as improved demand more than offset lower selling prices. Export sales revenue, however, was down 13%. J. E. (Ted) Newall, chairman, president, and chief executive officer, says lower prices in export markets, caused in part by the strength of the Canadian dollar, were the chief culprit.

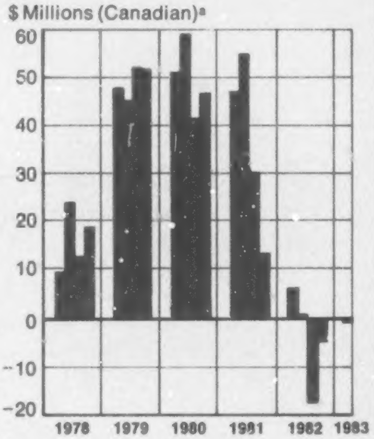
Sales of C-I-L Inc., the most diversified of the four companies, were $265 million, down 7% from the first quarter of 1982 but higher than the previous two quarters. C-I-L's profits also were down 57% to $2.6 million, but not so much as in the previous two periods.

President and chief executive officer Charles H. Hantho sees "some indications of modest improvement in economic activity" and expects seasonal improvement in earnings in the second quarter. But, although the Canadian recession is easing, Hantho thinks the industry still will face a period of lower growth rates and tougher international competition.

Union Carbide, however, saw both its sales and earnings slump in the first quarter. Sales dropped 15% to $155 million and the company lost $6 million on those sales. The company is particularly vulnerable to Canada's energy pricing policies and blames those policies for its tight cost-price squeeze.

Earl Anderson, New York

Combined earnings: chemical losses easing



a After-tax earnings of four largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont Canada, and Union Carbide Canada.

Some rays of hope shine on chemical sales and earnings

$ Millions (Canadian)	First-quarter 1983 Net sales	Change from 1982	Net income[a]	Change from 1982	Profit margin[b] 1983	Profit margin[b] 1982
C-I-L Inc.	$265.0	−7.1%	$2.6	−57.4%	1.0%	2.1%
Celanese Canada	94.1	19.1	1.5	66.7	1.6	1.1
Du Pont Canada	253.5	2.5	1.0	c	0.4	def
Union Carbide Canada	154.7	−14.9	−6.2	def	def	0.1
TOTAL	$767.3	−3.3%	$−1.1	def	def	0.8%

a Net income from continuous operations, excluding extraordinary gains or losses. b Net income as percentage of sales. c Deficit in 1982. def = deficit.

MAY 23, 1983

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NEWS

Rohm & Haas bares strategy for new business cycle Page 13

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Chemical capacity use finally moves up Page 7

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Cover: Cos-Mar's ethylbenzene-styrene complex at Carville, La. Photo courtesy of Badger, builder of the unit. Photo copyrighted by Ted Polumbaum

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CHEMICAL & ENGINEERING NEWS

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- **Extensive research on any sites chosen for radioactive waste disposal urged by NRC. Page 5**
- **Appeals to free Andrei Sakharov focus on the Soviet physicist's 62nd birthday. Page 5**
- **Hercules/Montedison venture in polypropylene will have annual capacity of 2.5 billion lb. Page 5**
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Chemical industry groups urge changes in trade laws to counter competition from government-controlled economies. **Page 18**

Government

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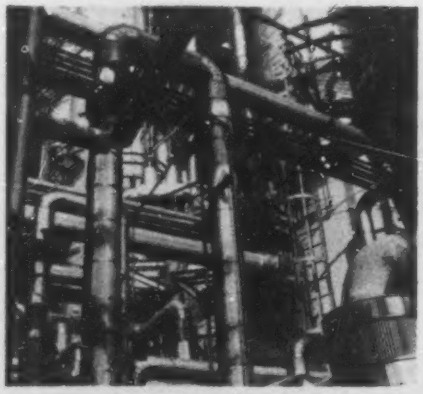
Makers of high-performance liquid chromatographs seek ways to improve instruments' speed, selectivity, and sensitivity. **Page 29**

Gibbs Medal

John D. Roberts, instrumental in developing proton NMR into a powerful tool for organic chemistry, wins ACS Gibbs Medal. **Page 32**



News Focus

Capacity use rates for the U.S. chemical industry are inching upward; polymers lead the way. Page 7

Chemical Capacity Use Finally Rebounds

U.S. chemical plants are running 64% of capacity, polymer plants, 71%, as a seemingly endless recession has at last given way to a fairly vigorous upturn

William F. Fallwell, C&EN Washington
Bruce F. Greek, C&EN Houston

Pennwalt chairman Edwin E. Tuttle said it for everybody in his company's first-quarter report: "Chemical operating rates are inching upward, and, although the situation is still far from satisfactory, we are delighted with the improvement that finally seems to be under way."

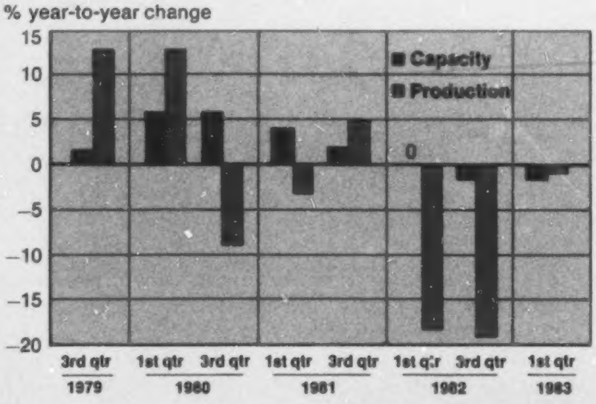
That's precisely the conclusion emerging from C&EN's semiannual capacity use survey of major U.S. basic chemicals and polymers. By themselves, the resulting data are still pretty depressing—it isn't the best of times when plants are running at less than two thirds of rated capacity. However, an underlying tide of market gains, especially in polymers, is beginning to have an effect. Plant use rates are now decidedly higher than a year ago.

C&EN's data undoubtedly understate the actual improvement that has taken place. At the moment, plant use rates are an upward-moving target. Because of the natural lag in use estimates by the many industry analysts assisting in the survey, resulting averages are for the first quarter of the year. Current second-quarter operations, from signals such as the April gain in the workweek, are up at least a few percentage points from the first quarter.

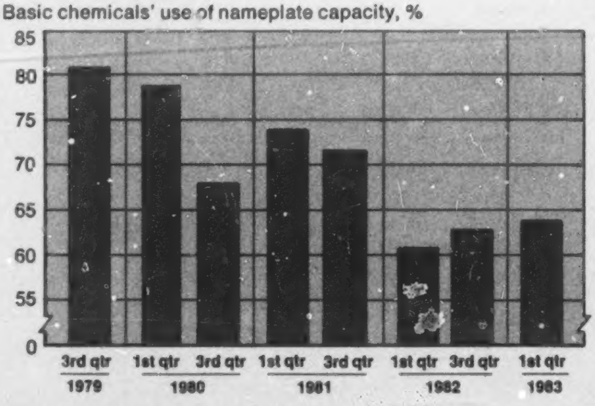
With this caveat, here are the main points emerging from the present survey of 32 basic chemicals and 11 polymers:

- Nameplate capacity use in the basic chemical group has crawled up another notch since last summer, reaching 64% in the first quarter. A year ago, at its lowest point, the figure was 61%. For perspective, the recent high point was 81% in mid-1979.
- Polymer plant use is moving sprightlier. The first-quarter reading of 71% is up from 69% last summer and

Chemical production fell much more than capacity in 1982 . . .



. . . leading to current low level of capacity use



Sources: Industry and government data, C&EN estimates

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Effective plant use in basic chemicals recovers to 70%

Billions of lb per year unless otherwise noted[a]	First-quarter 1983			Third-quarter 1982			First-quarter 1982		
	Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use	
		Nameplate	Effective		Nameplate	Effective		Nameplate	Effective
Petrochemicals—olefins and aromatics[b]									
Ethylene	39.0	67%	74%	39.0	61%	68%	39.7	56%	62%
Propylene (chemical and polymer)	23.0	49	54	23.0	56	62	23.0	44	48
Butadiene[c]	4.5	37	41	4.4	40	44	4.6	42	47
Benzene (bg)	2.3	43	48	2.4	48	53	2.4	44	49
***p*-Xylene**	4.9	68	72	4.9	60	63	5.5	54	57
Petrochemicals—C_1 derivatives									
Ammonia (mt)[d]	18.7	71	75	19.8	82	87	19.8	84	88
Urea (mt)[d]	7.8	73	81	7.8	72	80	7.8	65	73
Methanol (bg)	1.7	56	62	1.6	76	84	1.5	72	80
Formaldehyde (37% solution)	9.2	55	58	8.9	47	49	8.9	51	54
Chlor-alkalies									
Chlorine (mt)	14.4	67	71	14.6	64	67	14.8	62	65
Caustic soda (mt)	15.4	66	69	15.6	61	64	15.7	59	62
Soda ash (mt)	10.7	74	78	10.9	73	77	10.4	76	80
Acids[d]									
Sulfuric (mt)	57.5	59	62	59.6	49	52	59.4	54	57
Phosphoric (P_2O_5, mt)[e]	12.5	71	75	12.6	64	67	12.4	62	65
Industrial gases									
Oxygen **Nitrogen** } (total, liquid, ttd)	37.0	64	78	36.6	65	82	37.6	64	80
Carbon dioxide (ttd)	18.9	61	68	18.4	67	75	17.7	63	70
Mineral-based inorganics									
Sulfur (total, mlt)	15.5	48	—	15.8	53	—	15.7	61	—
Potash (mt)	2.2	86	—	2.7	74	—	2.7	84	—
Phosphorus (mt)	0.55	82	86	0.55	68	72	0.55	66	69
Plastics intermediates									
Styrene[f]	8.2	64	75	8.7	69	81	8.7	79	93
Vinyl chloride	10.1	65	72	10.0	68	76	9.6	50	56
Toluene diisocyanate	0.75	90	99	0.73	73	81	0.73	74	82
Fiber intermediates									
DMT-PTA[g]	7.3	64	75	7.3	56	66	7.3	58	68
Ethylene oxide	7.3	76	84	6.8	67	74	6.8	68	76
Cyclohexane	3.4	31	29	3.1	37	39	3.1	33	35
Adhesives, coatings intermediates									
Phenol[f]	3.6	64	71	3.6	61	68	4.0	56	62
Vinyl acetate	2.4	90	95	2.3	91	96	2.4	72	76
Pigments									
Carbon black	3.3	63	70	3.4	62	69	3.4	75	83
Titanium dioxide (mt)	1.0	60	71	1.0	61	72	1.0	53	62
Solvents									
Acetone[f]	3.3	57	63	3.3	53	59	3.6	59	66
Ethanol (mg)	240	72	76	240	75	79	270	50	53
Methylene chloride	0.83	59	66	0.83	63	70	0.83	54	60
AVERAGE		**64%**	**70%**		**63%**	**69%**		**61%**	**66%**

[a] bg = billions of gal, mt = millions of tons, tt = thousands of tons, ttd = thousands of tons per day, mlt = millions of long tons, mg = millions of gal. [b] About 25% of ethylene and lesser amounts of other capacity currently is shut down because of weak markets. [c] Total extraction capacity, which runs about 25% more than basic production capacity. [d] Some capacity, possibly 15%, shut down. [e] Includes both wet-process and furnace-process capacity. [f] Up to 10% of capacity currently shut down. [g] Dimethyl terephthalate and purified terephthalic acid, not including acid converted to DMT. **Sources:** Industry and government sources, C&EN estimates

66% a year ago. Polymers' last peak was 85% in early 1980.

- Plant use rates figured on effective top capacity (subtracting 5 to 15% of nameplate capacity because of inevitable glitches in operations) have reached 70% in basic chemicals and 77% in polymers. That's up from 66% and 71%, respectively, a year ago.

- Underneath these capacity use numbers, production is still down 1% from a year ago for the chemical group but is up 11% in polymers. At the same time, plant capacity has sunk 2% in chemicals and gained 3% in polymers. This drop in chemical capacity is very conservatively stated, since it doesn't include plants mothballed until economic conditions improve. Hence, the decline

Plant use has continued to pull up in plastics and synthetic fibers

	First-quarter 1983			Third-quarter 1982			First-quarter 1982		
	Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use	
Billions of lb per year		Nameplate	Effective		Nameplate	Effective		Nameplate	Effective
PLASTICS									
Polyethylene, low density	10.1	74%	79%	9.3	76%	81%	9.3	71%	76%
Polyvinyl chloride	8.9	55	64	8.4	59	69	8.4	59	69
Polyethylene, high density	6.3	85	89	6.1	82	86	6.1	66	69
Polypropylene	5.1	83	92	5.1	61	68	5.1	67	74
Polystyrene[a]	5.3	55	65	5.3	60	71	5.3	53	62
AVERAGE		**70%**	**78%**		**68%**	**75%**		**64%**	**71%**
SYNTHETIC FIBERS									
Filament yarn									
Polyester	1.6	83	88	1.6	76	81	1.8	74	79
Nylon	1.9	64	68	2.0	64	68	2.0	60	64
Olefin	1.0	48	51	0.99	60	64	0.99	64	68
Staple									
Polyester	2.7	75	80	2.8	62	66	2.8	77	82
Nylon	0.98	81	86	0.99	76	81	1.0	56	60
Acrylic	0.83	77	82	0.84	82	87	0.84	71	76
AVERAGE		**71%**	**76%**		**70%**	**75%**		**67%**	**72%**
OVERALL AVERAGE		**71%**	**77%**		**69%**	**75%**		**66%**	**71%**

[a] Between 5 and 10% of this capacity is shut down. **Sources:** Industry sources, Society of the Plastics Industry, Textile Economics Bureau, C&EN estimates

only hints at the drastic pruning companies have undertaken in reaction to the miserable economy of the past three years.

Such "rationalizing" of operations has left companies fairly optimistic as recovery gets under way. Tuttle at Pennwalt isn't the only one noting some progress. In Dow Chemical's first-quarter report, president Paul F. Oreffice says: "We are encouraged by the steadily increasing daily sales rate of our principal products each month."

Du Pont puts some specific numbers behind a similar view. Chairman Edward G. Jefferson says the company's chemical arm had an overall pickup in sales compared to capacity from 62% in January to 72% in March. "We are finally emerging from the worst recession since World War II. For Du Pont, the recession touched bottom in December and January. Our chemicals plastics, fibers, and specialty products businesses have shown steady improvement in demand since early February."

Some of the specific output estimates in C&EN's present survey bear out Jefferson's observation. And as might be expected, recovery has not been uniform in the industry. Some products have hit the expansion trail much earlier than others, leaving a highly mixed situation.

Take, for example, two product groups—thermoplastics and basic petrochemicals—at opposite ends of the chemical production chain. In a typical recovery pattern, the resins are moving up much earlier than are petrochemicals, since plastics are closer to final consumer demand creating the economic recovery. For the five leading thermoplastics in C&EN's survey—high-density and low-density polyethylene, polyvinyl chloride, polypropylene, and polystyrene—output is up 6% from third-quarter 1982 and a rousing 14% from first-quarter 1982. Producers seem to sense the upswing and have kept these polymers the only major area with continuing plant expansion. Capacity for the five resins is up 4% from a year ago. As a result, capacity use has pushed up to 70% from 64% over the past year.

By contrast, the sluggish petrochemicals show only a 2% production gain from a year ago and a capacity drop of 2%. That leaves capacity use for this group of five chemicals—ethylene, propylene, butadiene, benzene, and *p*-xylene—dragging along at 56%, barely up from 54% in early 1982. Telling evidence of this slow motion came in oil companies' first-quarter reports on their chemical operations. For a group of seven companies surveyed by C&EN, petrochemical profits virtually disappeared (C&EN, May 16, page 23).

The kingpin among these petrochemicals is ethylene, which is the building block for so many downstream chemicals and plastics. Ethylene is close to the industry average in plant use, and its problems are a good illustration of the lagging condition of most basic chemicals in the economic recovery. The state of industry data on ethylene also tells a lot about the difficulty in pinning down how hard plants actually are operating.

Use of ethylene's nameplate capacity in the first quarter was about 67%. That's based on a highly optimistic estimate of 39 billion lb per year for capacity. However, up to 20% of this capacity is shut down because of poor markets, and some of it may never start up again. Hence, plants currently operating are running close to 80% of nameplate capacity. That's still not good enough for much profit to producers, who are having a hard time floating even a half-cent-per-lb price increase. There's simply too much slack in capacity and too little movement in markets.

If that isn't bad enough, other petrochemicals make ethylene look rich. In one of the worst cases, butadiene actually has slumped a bit in production from

C&EN's capacity use indicator: the ground rules

Capacity use at chemical plants is difficult to measure and requires certain assumptions. These bring some order to the maze of variables affecting this critical indicator of the industry's health.

With the help of industry and government sources, C&EN measures capacity use as a percentage of both nameplate and effective maximums. Nameplate capacity is the official design capacity of plants. Effective capacity is the practical maximum after reductions for unplanned maintenance, corrosion problems, changes in product mix, and other influences. Although engineering companies and industry statistics groups try to make nameplate capacity data as real as possible, practical problems almost always reduce effective maximums to 85 to 95% of the official totals. For short periods, plants can run more than 100% of effective top capacity, but such a rate won't last more than a few months.

Capacity use is given over as much of a calendar quarter as production data permit, with no seasonal adjustment. The figures are for plants actually operable. At present, some products such as ethylene, phenol/acetone, polystyrene, ammonia, and urea have plants temporarily shut down because of weak markets. These plants still are included in capacity totals. The totals exclude new plants just starting up and old plants out of operation for long periods because of accidents. As much as possible, capacity figures stay current with expansions.

Capacity data don't take into account other temporary fluctuations for fuel and electric power interruptions, equipment failure, and feedstock scarcity or substitution. The feedstock variables, for example, have been important in the past few years in ethylene production, altering maximum output for several coproducts such as propylene, butadiene, and benzene.

Products in C&EN's capacity use survey are the same as those in the Key Chemicals and Key Polymers series. These are the core products of the industry, the building blocks leading to downstream production of thousands of more specialized products.

a year ago, so rated capacity of 4.5 billion lb per year is running at a lowly 37%. Needless to say, many plants for making this chemical also are currently shut down. Ditto for the leading aromatic, benzene, which has a capacity use estimate of 43% for the first quarter. No wonder benzene has had almost continuous downward price pressure.

Among the C_1-based petrochemicals, recovery is also distant for most. A special problem in farm markets probably will delay any pickup another year for certain products such as ammonia. Ammonia production has fallen sharply over the past year. Plant use, even with less official capacity, has dropped to 71% from 84% in early 1982. Urea plant use isn't much better at 73%. And methanol, despite the upswing in its important housing market, sputters along at 56% plant use. The major plant investment in methanol in the past few years has not paid off, and the product's pricing is in shambles. Discounts have reached one third from list prices.

One of the few expansions this year is PPG and Du Pont's joint ethylene glycol plant at Beaumont, Tex.

Among intermediates a step or two downstream from these petrochemicals, there has been some upward motion in capacity use. An example is vinyl chloride, which has climbed to 65% from 50% in early 1982 on the new strength in the housing market for polyvinyl chloride. Another intermediate showing some life is ethylene oxide, moving up to 76% from 68% as its important market in polyester fiber awakens. That's also the case for the other major polyester precursor, dimethyl terephthalate/terephthalic acid, whose capacity use has picked up to 64% from 58%.

Overall figures for fibers don't show much motion to date, but some of the individual fibers have improved markedly. For the group of six fiber types in C&EN's survey—filament and staple polyester, filament and staple nylon, olefin filament, and acrylic staple—capacity use has moved up to 71% in first-quarter 1983 from 67% in first-quarter 1982. However, in the best case, polyester filament plants ran at 83% of capacity this year, up from 74% in early 1982. Polyester producers have become quietly optimistic, and some sources in this area say tight market conditions could be less than a year away. Similarly, nylon staple has improved greatly over the past 12 months, with capacity use up to 81% this year. Here, the housing upsurge has boosted nylon's important carpet market. ☐

MAY 30, 1983

CHEMICAL & ENGINEERING NEWS

Synthetic fibers lead way
in chemical industry recovery
A Key Polymers Review Page 11

A1250-1 6/1/83

Scientific journals

Rising costs, falling circulation Page 31

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Cover: A chemical journal threads through printing press at Mack Printing Co., Easton, Pa. Photo by C&EN's Ernest L. Carpenter

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CHEMICAL & ENGINEERING NEWS

MAY 30, 1983

News of the Week

- **Chemical solar cell developed by Standard Oil (Ind.) is much more efficient than earlier cells.** Page 6
- **National Medal of Science given to eight who work in chemistry or related fields.** Page 7
- **Celanese buys out partner ICI's share of Fiber Industries.** Page 7
- **GE's electric power generator using superconducting magnets tested successfully.** Page 8
- **Environmental regulations are not the top consideration in siting new plants.** Page 8
- **George E. Heinze elected to ACS Board as Region III director.** Page 8

Business

Synthetic fibers producers are optimistic that turnaround in demand, production, and profits will last through 1984. **Page 11**

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Western Europe's chemical industry is coming out of its slump; first-quarter earnings of major firms are encouraging. **Page 16**

Government

Defense Department's plan to make new binary chemical weapons gets potshots; GAO says reasons are not convincing. **Page 22**

Science

New technique allows two-carbon sequences to be inserted into molecules of any desired asymmetric configuration. **Page 27**

Agricultural chemicals offer challenge in development and use; problems are similar to those of pharmaceutical industry. **Page 28**

Education

Two programs set up to improve science education—Harvard will train midcareer scientists to teach; Wisconsin proposes institute to foster research in chemical education issues. **Page 30**

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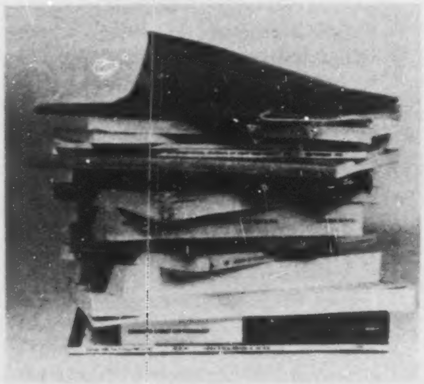


Special Report

Falling circulation, rising costs of paper, production, postage plague publishers of scientific journals. Page 31

Major Synthetic Fibers Well Into Long-Awaited Recovery

Markets could even get tight for some grades, as polyester, nylon, and acrylic move briskly out of the recession; imports still may be problem

Bruce F. Greek, C&EN Houston

U.S. synthetic fiber producers have been quietly convinced ever since the late 1970s that their day in the sun wasn't far away. Although the stop-and-go recession of the past three years kept that day from arriving, 1983 and 1984 could bring it in.

Of course, with the tricky fibers market, all forecasts have to be in the conditional. In the past, prosperity time and again has touched fibers for a year or two only to vanish in five to 10 years of turmoil. That's what happened after the early 1970s bonanza. For the rest of the decade, major fibers went through a numbing round of plant closings, poor growth, and financial distress.

But fibers people think they have paid the price now and will get something better. Evidence so far this year bears them out. And if they're right, it's good news for the entire chemical industry. Fibers traditionally are a leading-indicator product group.

At the moment, resurgence in fibers demand continues after a fitful start late in 1982. For some fibers, the rebound is building good strength and likely will carry into 1984. That would bring production to above the levels of 1981, the last good year for this $6.6 billion segment of the chemical industry. Variations still will exist in the fortunes of the different polyester, nylon, and acrylic grades covered in the following pages. Some are well ahead of the averages, and some lag.

It all depends on which markets are involved. Fibers with the best current prospects are going heavily into home furnishings, where demand is spurred by the large upturn in housing starts this year. Apparel uses rank second in the market outlook for the next few years. Here, inventory-cutting has been completed, and new inventories held down. For polyester, a good increase in apparel-related export markets is likely.

Key Polymers

These recovery prospects will make the fibers business a better money maker. The largest fibers producer, Du Pont, already reports higher fiber profits in the first quarter, rising 38% on a 4% sales gain. Similarly, Celanese reports that its U.S. polyester profits nearly doubled in the first quarter from early 1982. Monsanto comments that fiber volume, demand, and shipments were better in the quarter than a year ago. Allied comments that sales increased significantly in carpet fibers, contributing to an 86% profits gain in the company's combined chemicals and polymers business.

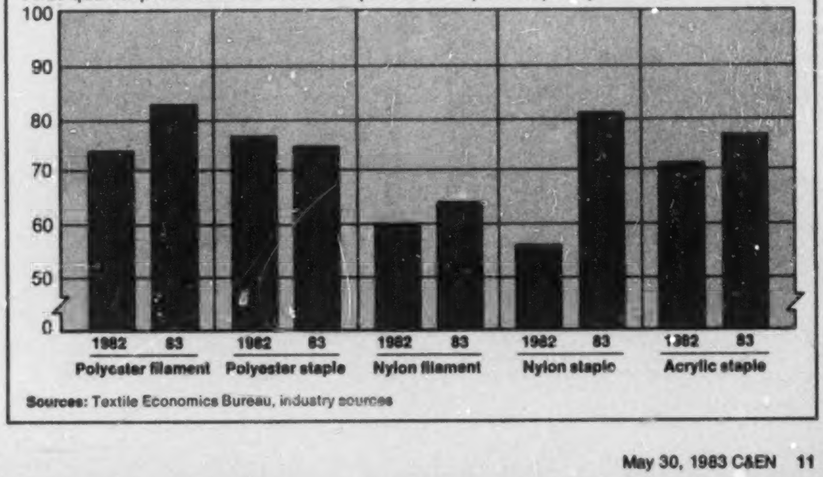
As production grows, higher plant operating rates are assured because no capacity additions of any size are in the works for the next two years. For some forms of the three large-volume fibers, capacity has all the earmarks of becoming tight later this year and beyond.

Actually, fiber capacity has been slipping gradually for many years. Most of the recent decline has been in polyester, but nylon also has been hit. Unless another severe recession comes along, however, analysts expect that capacity will just about hold at present levels through the rest of the decade.

Combined production of the three major fibers could total nearly 6.5 billion lb in 1983, up 14% from 1982

Plant use in polyester filament and nylon staple pushes over 80%

First-quarter production as % of first-quarter nameplate capacity



Sources: Textile Economics Bureau, industry sources but still below 1981's 7.2 billion lb. At the current clip of monthly shipments increases, 1984 production could easily exceed 1981 levels. These fiber data are current estimates from industry sources and past figures from the Textile Economics Bureau.

Capacity use this year could be close to 80% of the combined first-quarter nameplate total. This is well above 1982, when capacity use fell below 70%, even without counting polyester capacity shut down during the year. If 1984 brings out another 1 billion lb of fiber production, plants will have to run well above 90% of capacity, bringing back the boom conditions of the early 1970s.

Already, the improved level of plant operations has led to a sharp drop in fibers' ratio of inventories to shipments. The rule of thumb here is that, under normal business conditions, companies should keep about a one-month supply of product in stock. More than that tends to mean oversupply, and less means a tightening market. Over the past year, inventories have dropped from a four- to five-week supply to a bit more than three. In one of the more dramatic examples, the ratio for nylon staple has tumbled from 1.19 to 0.80. Capacity use has jumped from 56% to 81%. This nylon type, which goes heavily into carpets, is well on its way toward a sellers' market.

Firming up prices for these fibers is very much on producers' minds. Price hikes might well be expected amid rising production, but for fibers, there have been too many cases of profitless prosperity as in the 1970s. Producers pushed to keep sales volume up at the expense of price increases.

So far in 1983, too, most of the gain in fiber value has come in physical volume instead of price. In 1983, sales value of the three major fibers probably will exceed $6.6 billion, up 12% from $5.9 billion in 1982. With minor price increases and a substantial volume increase in 1984, sales value certainly will exceed 1981's $7 billion.

But there could be a catch. Higher fiber prices could put a damper on production if price hikes hurt U.S. apparel manufacturers in their all-out competition with imports. Even fiber exports (some of which return as clothing) could decline if they become uncompetitive with fibers from Europe, Japan, or developing countries.

There is an unfortunate analogy to the U.S. steel industry. Steel costs rose so much that imported steel grew from negligible to very sizable. Steel outlets such as automobiles also became more expensive, and foreign autos garnered a quarter or more of the U.S. market. In the same way later this decade, markets for apparel and other finished goods made from fibers may be wrested away by imports. The large share of the acrylic sweater market currently taken by imports could be a sign of things to come.

Higher fiber prices also could hurt synthetic fibers in their competition with natural fibers. In some cases, such as carpets, synthetic fibers have literally taken over and are considered quite safe from competing inroads. However, apparel markets are another matter. There's always a threat hanging over them from natural fibers, especially cotton.

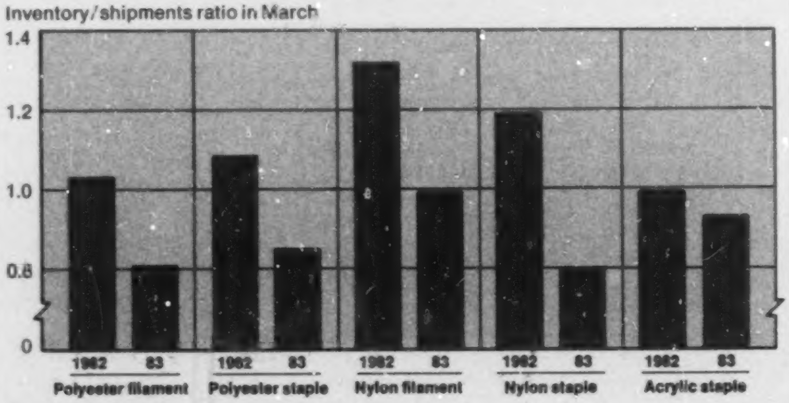
The biggest tussle is between cotton and polyester. The cotton price bounces around, influenced by weather, politics, fashion, and other highly unpredictable factors. This year the cotton price is high, with cotton futures priced even higher. Experts expect further increases, although not to the levels of 1980 and 1981. They add that this price rise may continue through the 1980s as cotton farmers find cattle and soybeans more profitable. This augurs well for synthetic fibers, especially polyester.

But again, higher cotton prices, coupled with higher demand and prices for polyester, will make U.S. apparel markets more attractive to imports, especially from developing countries that want the jobs in labor-heavy textiles. So the economic balance wheel may swing toward easing demand for U.S.-produced polyester.

Some apparel imports will be made from U.S. fiber exports. However, these would hardly offset the imports' impact on U.S. fiber demand. A typical result is the current controversy involving China, which radically reduced polyester imports from the U.S. in 1982 in response to U.S. restrictions on clothing imports. Negotiations are under way to resolve the impasse. Polyester producers wish for success here because their forecasts depend on increased exports, a good bit of which would go to China. On that assumption, analysts say polyester exports could exceed 500 million lb this year or one seventh of estimated production.

At home, the smaller-volume industrial uses of synthetic fibers often have been the frosting on the cake, but lately the frosting has been thin. Tire cord, a large outlet, is the problem. Changes in tire cord favoring steel and the rise in auto imports combine to make the outlook for industrial fiber uses one of minor growth. The business recovery will help now, but a return to 1981 levels may take some time.

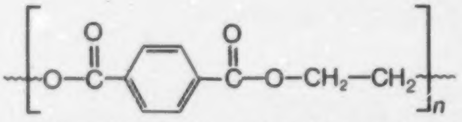
Fiber inventories have tightened drastically over past year



Source: Textile Economics Bureau

Key Polymers

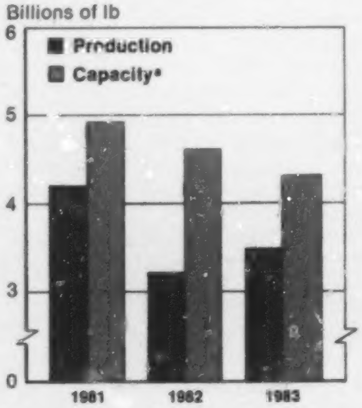
Polyester



Poly(ethylene terephthalate)

- ***Demand well up***
- ***Capacity down***
- ***Prices up a bit***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Reaction of dimethyl terephthalate or terephthalic acid with ethylene glycol to produce bis(2-hydroxyethyl)-terephthalate, which is catalytically polymerized to poly(ethylene terephthalate)

MAJOR END USES (U.S.)

Apparel 60%, home furnishings 20%, industrial uses 10%

FOREIGN TRADE

Exports—may reach 500 million lb in 1983; imports—small, may rise to 15 million lb in 1983

PRICES

150-denier textured filament 95 cents to $1.10 per lb; 150-denier feeder filament, 80 cents per lb; staple 85 cents per lb; variable discounts

COMMERCIAL VALUE

$3 billion for production, 1983

Predicting the fortunes of polyester fiber is one of the finer arts, since the picture includes everything from Chinese diplomacy to the boll weevil. Forecasts cover quite a range this year, but everyone agrees, the direction is up.

Polyester has begun recovery from a very bad 1982, when U.S. production fell a thumping 24% to 3.2 billion lb. Even a strong upturn in 1983 won't fully overcome that drop. Much depends on the shifting outlets of apparel and exports. The latter are hung up at the moment in trade negotiations between the U.S. and China. Analysts hope the China outlet will open up late in the year.

Of many different polyester forecasts for 1983, the majority look for about a 10% pickup in output to about 3.5 billion lb. Optimists envision a production increase of nearly 20% to 3.75 billion lb. Pessimists put the total down to 3.4 billion lb.

Plant capacity for polyester continued to decline in 1982 as in 1981. As 1983 opened, nameplate capacity was about 4.3 billion lb per year of the various fiber types. If production this year totals 3.5 billion lb, the average operating rate would come close to 82%.

However, there is quite a split in the capacity use situation. Plants making polyester filament (continuous yarn) currently are running at a higher rate than are plants turning out staple (chopped fiber). The textile filament part of the capacity is stronger yet compared to other types such as industrial monofilament. Because of this strength, filament producers apparently are succeeding in a price increase in early May—something that has proved quite difficult in recent years.

One reason a price hike has a better chance now is that polyester inventories are relatively snug. In both filament and staple, Textile Economics Bureau data show well under a one-month supply in storage at producers.

Apparel uses are behind the current surge in polyester filament demand. In 1983, this outlet might take as much as 1 billion lb of fiber, up from 800 million lb in 1982. There's strong potential for rebuilding demand in this area because in the economic downturn, apparel cost the fiber as much as 400 million lb in lost sales over 18 months in 1981 and 1982.

Apparel uses of staple also have picked up because of the improved economy and higher prices for competing cotton. Some analysts noted a turn in apparel demand for polyester staple at the start of fourth-quarter 1982. The shift has continued, allowing a big reduction in inventories and generally stable, though still discounted, prices.

The widely used blends of polyester staple with cotton and wool can be shifted by official label changes or by small fractions without changes in labeling. Such changes, because of the volume involved, can have a big impact on staple demand. For example, the government's agricultural payment-in-kind program designed to reduce planted acreage in 1983 will cut cotton production, already has raised cotton prices, and may cause an official shift toward the high end of the polyester-cotton ratio in shirts, dresses, and the like. However, analysts say it would take a major increase in the cotton price to cause an official ratio change because of the costs involved in new labels, machinery adjustments, and promotion. Even then, some observers doubt the success of high-polyester-content blends because of the sacrifice seen by many customers in esthetics and feel.

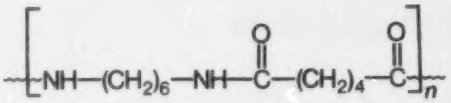
The smaller home furnishings market for polyester also is turning up in demand growth from the housing upswing. Current views are that the various uses in housing—carpets, bedding, draperies, and so on—all will increase, with carpets possibly the slowest. Bedding has done somewhat better because of energy saving concerns which have helped sale of comforters and blankets.

Industrial uses of polyester fiber will aid production less than will apparel and home furnishings. Tire cord consumption will do well just to hold level this year even with higher car production because of the shift to radial tires. Use of polyester in belts and other reinforcing applications also is not expected to grow much.

Overall, the outlook for polyester is the most variable of the major synthetic fibers. U.S. use will increase 10% or more if the economy continues its steady recovery. If exports to China get cracking later in 1983, production could get a considerable extra push carrying into 1984.

Key Polymers

Nylon

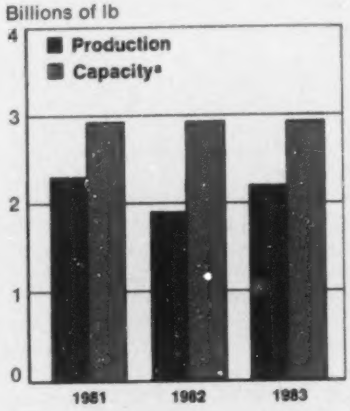


$$\left[-NH-(CH_2)_6-NH-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}- \right]_n$$

Nylon 66

- ***Demand strengthening***
- ***Capacity flat***
- ***Prices firmer***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Nylon 66—reaction of adipic acid and hexamethylenediamine to form hexamethylene diammonium adipate, which is polymerized by removal of water; nylon 6—polymerization of caprolactam by addition and subsequent removal of water

MAJOR END USES

Home furnishings 60%, apparel 25%, industrial uses 15%

FOREIGN TRADE

Exports—declining to about 100 million lb in 1983, imports—up slightly to about 25 million lb in 1983

PRICES

Carpet staple $1.15 to $1.20 per lb; apparel grades $1.80 to $2.40 a lb; some discounting

COMMERCIAL VALUE

$3 billion for production, 1983

In the popular mind, nylon is associated with clothes. But actually, the nylon market is heavily weighted toward construction, which takes about 60% of production in carpets and other uses. This year, that's good; but last year, it wasn't. So nylon has a strong recovery in progress and stands to gain more than any other major fiber from the big pickup under way in big-ticket U.S. consumer durables.

In fact, nylon could make it back all the way this year from last year's drop, although most opinion isn't quite this optimistic. Analysts generally believe full recovery will wait until 1984.

Current thinking is that nylon production, including 66 and 6 types and aramid, probably will reach 2.2 billion lb this year, up at least 15% from 1982. Some analysts hold out hope for an extra 130 million lb of production, bringing the 1983 total to 2.33 billion lb. This high estimate still would be below the all-time high of 2.55 billion lb in 1979.

Plant capacity in nylon changes slightly each year, fluctuating around 2.9 billion lb. In 1983, for example, some capacity will close permanently at Du Pont. But this drop could be offset by debottlenecking at other plants and possible small-scale expansions for some of the specialty types.

With an average capacity estimate of 2.9 billion lb, the industry will operate at more than 75% of the nameplate total in 1983, up substantially from 66% in 1982. The 1983 operating rate could close in on 80% toward the end of the year.

Of the two major nylon types, there is more than twice as much capacity for nylon 66 (made from adipic acid and hexamethylenediamine) than nylon 6 (made from caprolactam). Differences in physical properties between these two are small enough that the fibers can be used interchangeably in most applications. There is a sharp producer split between the two, with Du Pont and Monsanto the powers in nylon 66, and Allied, Akzona, and Badische in nylon 6.

The big home furnishings market, dominated by carpet, provides nylon's major ups and downs. The decline in home building beginning in 1981 hit nylon especially hard with a combination of sales declines and inventory chopping. The decline in carpet use alone more than accounted for the decline in all nylon fiber shipments in 1982.

Now that home building has started to improve, the outlook for nylon is brightening rapidly, especially for staple. Although houses are smaller now, partly because of a higher fraction of multifamily dwellings, nylon carpeting is still growing in volume. Some of the reason is that new-home sales stimulate used-home sales, and buyers of old houses frequently replace carpets.

Other nylon uses in home furnishings are small. For example, the upholstery outlet is just a few per cent of carpet volume. It's making a good gain this year but can't have much effect on total nylon demand.

The apparel market, about a quarter of total U.S. nylon demand, also is growing briskly, especially for nylon filament. Fashion has a significant impact here. For example, the popularity of lightweight outerwear and sportswear at the moment has given nylon a nice growth market. Some apparel uses such as hosiery are old standbys, less affected by the economy and fashion but not expected to grow much either. A few small apparel uses such as sweaters are declining.

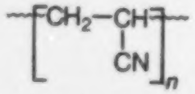
Industrial uses make up less than 15% of the nylon fiber consumption in the U.S. A big part of this outlet is tire cord, now mainly for off-the-road and/or oversized truck tires and specialty products such as aircraft tires. Passenger car markets for nylon have declined drastically with the explosive inroads of radial tires.

After a steady decline, nylon tire cord demand may have bottomed out, analysts believe, and could begin to grow again slowly. Use of heavy-duty tires depends on the general economy. With commercial and industrial construction currently lagging, a significant upturn for tires for construction equipment could be some time off. Other industrial uses in belting, hose reinforcement, webbings, luggage, and so on are small, and pickups in these uses won't help total nylon demand very much.

Fortunately, nylon doesn't have to wait for big new commercial construction projects or a new capital spending wave in industry. All nylon needs this year is continued vigor in housing.

Key Polymers

Acrylic

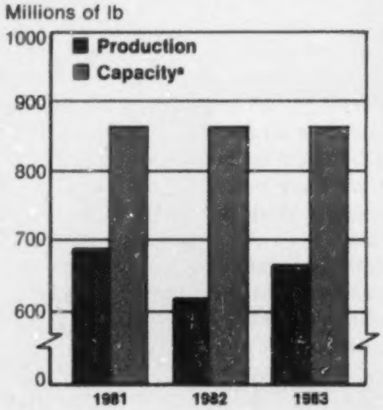


$$-\!\!\left[CH_2-\underset{CN}{\underset{|}{CH}}\right]_n\!\!-$$

Polyacrylonitrile

- ***Demand improving***
- ***Capacity stable***
- ***Prices steady***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Polymerization of acrylonitrile, which is made by catalytic reaction of ammonia and propylene

MAJOR END USES (U.S.)

Apparel 65%, home furnishings 30%, industrial uses 5%

FOREIGN TRADE

Exports—rising in 1983 to about 200 million lb, imports—holding at 10 million lb or less

PRICES

3-denier staple for apparel $1.00 to $1.10 per lb; discounting significant

COMMERCIAL VALUE

$600 million for production, 1983

Acrylic is a singular fibers business and sometimes goes its own way. It's the most apparel-oriented major fiber (65% of demand) and by far the most international, with exports taking 30% of U.S. production. Exports are expected to do well this year. However, acrylic can't cash in on the upsurge in U.S. housing so much as nylon can. The net result: Acrylic is expected to have a decent recovery but no boom.

As American Cyanamid pointed out in its first-quarter report, acrylic had a fast-rising start for the year. For now, acrylic analysts think the fiber will wind up 1983 with a moderate production increase after two years of decline. This improvement for a fiber somewhat in eclipse in recent years, especially in U.S. use, is good news to struggling acrylic producers. Longer term, if the production increase continues, one analyst ventures, acrylic fibers will be a good business providing acceptable profitability.

This year's production growth is forecast at 7 to 10%, bringing output to about 670 million lb. In 1982, production fell 10% to 620 million lb. The record was 780 million lb in 1980.

Total capacity for the various acrylic fiber types has plateaued near its peak of 860 million lb per year. It probably will hold here for some time except for the inevitable debottlenecking, which takes a while to appear in capacity estimates. The Textile Economics Bureau's official capacity listing is a slightly lower 830 million lb for late 1982.

For 1983, if production reaches 670 million lb, capacity use will average 78%. This is good for acrylic although not so high as expected for other major fibers. However, since acrylic has largely depreciated plants and little if any increase in feedstock costs, 78% operation suggests considerably better profitability.

But acrylic is not without problems. Middling capacity use stems mainly from a major wave of imports of finished acrylic clothing, which reduces potential acrylic fiber sale to manufacturers in the U.S. These imports aren't likely to go away soon.

True, the imports indirectly help U.S. acrylic fiber's important exports, which are forecast to zoom to about 200 million lb in 1983 from 127 million lb in 1982 and account for 30% of production. The rise in exports will be greater than the rise forecast for production, by 25 million lb or so. This hints another import-related drop in the U.S. outlet for acrylic. This outlet for U.S. producers has slumped about 30% from its peak back in 1973. In other words, exports are critically important to U.S. acrylic fiber growth.

As might be expected, imported acrylic clothing is the kind with relatively high labor costs, such as sweaters. By contrast, acrylic socks are made mainly in this country.

Imports of raw acrylic fiber have been falling, as might be expected from the size of unused U.S. plant capacity and consequent discounting of prices. Imports were down to a smallish 10 million lb in 1982 and are expected to hold at this level even with the improving U.S. market outlook.

Use patterns of acrylic fiber in the U.S. change little with time except for ups and downs in sweaters. High fashion changes from year to year, causing ripples in sweater demand. Currently, an upturn in demand for expensive U.S.-made acrylic sweaters is partly offsetting the market loss in lower-cost imported sweaters.

Another major area of acrylic apparel use which seems to maintain its position is "craft yarns" bought to be knitted into sweaters and other clothing items. These yarns require minimal labor in fabrication and distribution, thereby making imports very small. Craft yarns are roughly equal in market size with hosiery, sweaters, and pile fabrics.

Home furnishing uses of acrylic fiber are mainly in carpets and blankets, although there are many smaller uses. The economic recovery and home building upsurge are expected to boost demand for acrylic in furnishings relatively faster than in apparel but with less impact in terms of actual poundage.

Industrial uses of acrylic fibers are small. They range widely, from boat sails to filters.

With some help in industrial and housing uses this year and another nick in some U.S.-made textiles, acrylic will need every pound it can get in exports. At the moment, the overall data look good, and the fiber is becoming a much better business.

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JUNE 6, 1983

CHEMICAL & ENGINEERING NEWS

DIOXIN

A C&EN SPECIAL ISSUE

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CHEMICAL & ENGINEERING NEWS

JUNE 6, 1983

News of the Week

- **Dow Chemical will spend almost $3 million to study health effects of dioxin in the Midland area.** Page 8
- **White House announces final plan to abolish Commerce Department and set up trade department.** Page 9
- **Economic progress does not lead to adverse effects on the environment, says vice president George Bush.** Page 9
- **Monsanto soon will withdraw completely from synthetic fiber production in Europe.** Page 9

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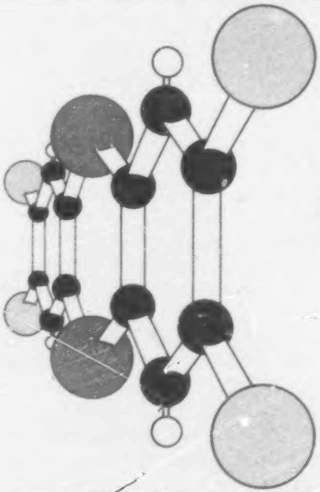


DIOXIN REPORT

2,3,7,8-Tetrachlorodibenzo-*p*-dioxin, though found in minute quantities, has made a giant impact as a potential hazard. Page 20

History

Three different types of exposure to dioxin—agent orange in Vietnam; Times Beach, Mo.; and Michigan river fish—led to the present concern over its effects on humans. **Page 23**

Toxicity

Studies of the contaminant have proved its toxicity to some but not all animals; its long-term effects on humans are unknown. **Page 37**

Origin

A by-product of commercial processes to produce chlorinated organics, dioxins are difficult to dispose of. **Page 51**

Litigation

Lacking a precedent, dioxin producers and the insurance industry are struggling for answers in their concern over the multiple lawsuits pending, particularly by Vietnam war veterans. **Page 57**

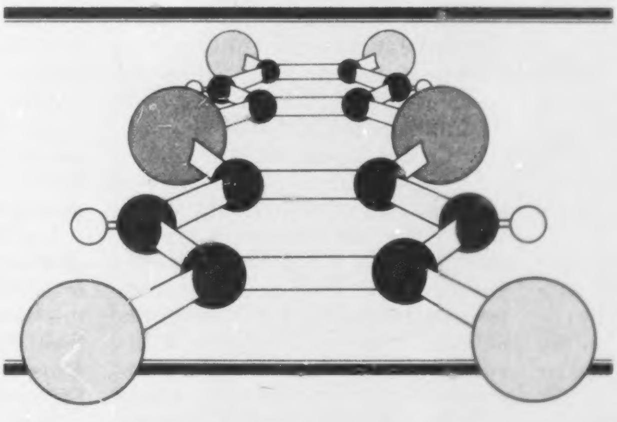
European scene

The 1976 accident in Seveso, Italy, that exposed a town to dioxin contamination was only the beginning of a continentwide scandal over disposal of the toxic wastes generated. **Page 61**

Dioxin Issue Focuses on Three Major Controversies in U.S.

Furor developing around the question of dioxin exposure has reached a head in three historic cases—agent orange, Times Beach, and Tittabawassee River

Janice R. Long,
David J. Hanson,
C&EN Washington



When the history of human problems with exposure to toxic chemicals is discussed in the years to come, one of the principal topics of debate will be the effects of the compound called dioxin. And, in that debate, if it focuses on the U.S., three names will be recalled—agent orange, Times Beach, and the Tittabawassee River.

More than any other incidents, these three widely differing examples of dioxin exposure point out the problems our scientific, regulatory, and legal systems have in handling the undefined hazards of potentially very dangerous substances.

Central to the entire problem is the herbicide 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Developed during World War II, it was first registered in the U.S. as a pesticide March 2, 1948, and it has been the subject of considerable study ever since.

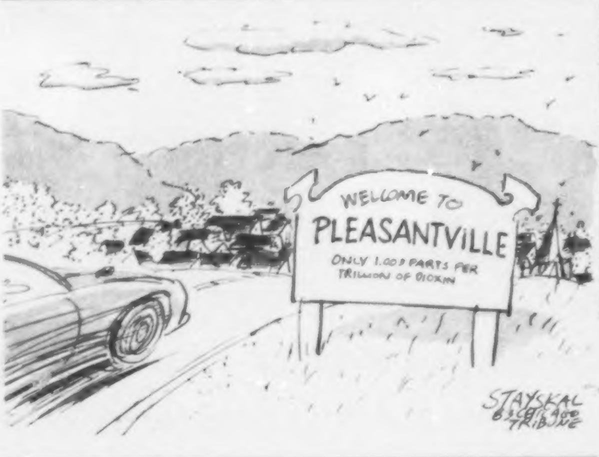
There were some health problems associated with 2,4,5-T almost from the beginning. In 1949, an industrial accident at a Monsanto plant in Nitro, W.Va., exposed 250 workers to the compound, with a number of resulting illnesses. But it wasn't until about 1955 that the cause of the illnesses, mostly the severe skin rash called chloracne, was found. West German physician Karl Schulz, treating workers from a Boehringer Ingelheim pesticide plant in that year, identified 2,3,7,8-tetrachlorodibenzo-*p*-dioxin as the cause of the chloracne. Schulz's work was published in West Germany in 1957, and appeared in *Chemical Abstracts* in December 1958.

Still, despite this problem, 2,4,5-T was considered a good herbicide and its use spread. It was used extensively on rangeland and pastures to kill unwanted weeds, and also on rice and nursery crops. Because 2,4,5-T is quite biodegradable and works so well, it, as well as other herbicides (particularly 2,4-dichlorophenoxyacetic acid) was considered by the military in the early 1960s as the best means of defoliating large sections of forest in Vietnam to take away cover from the enemy.

Spraying began in Vietnam in January 1962, using a variety of herbicide concoctions. Only small amounts were used at first, but the amounts jumped at the end of 1965 and heavy use continued until 1969, when mounting concerns about damage to Vietnam's ecology led to a tapering off and finally a halt to the spraying of 2,4,5-T in 1970. Of the seven or so herbicide formulations used, the most significant was called agent orange, an oily liquid that was a 50-50 mixture of the *n*-butyl esters of 2,4,5-T and 2,4-D.

However, because the 2,4,5-T was contaminated with dioxin, and because during this time it was discovered that dioxin is frighteningly toxic in some animals, and because an unknown number of U.S. personnel were exposed to the herbicide while in Vietnam, an exceedingly complex problem has arisen.

Vietnam veterans, learning from press accounts during the 1970s that dioxin was hazardous and that they might have been exposed, began to ask the Veterans Administration some tough questions. The Chicago VA office really started things moving when a case worker there asked veterans about their possible exposure to agent orange and any subsequent illnesses. She compiled a list of apparently affected veterans that



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found its way into the hands of a local news producer who made a documentary pointing out the possible connection.

As a result of the fears raised by this and other accounts, VA reports that as of May 1 of this year, 17,068 veterans have put in claims for disability payments because of agent orange exposure, and VA hospitals have treated 369,000 outpatients and hospitalized 9600 veterans who claim their medical problems are related to dioxin exposure. (These numbers also included a relatively small number of veterans seeking help because of radiation exposure during early atomic bomb tests.)

The problem, according to VA, is that it has essentially no evidence that the variety of complaints being described by the veterans had anything to do with exposure to agent orange or its dioxin contaminant. Consequently, VA has balked at offering compensation.

Part of VA's reason for rejecting the agent orange connection is a large amount of data compiled by the Air Force in the early 1970s on the use and fate of the herbicide and its contaminant, dioxin. This work finds, in general, that the herbicide, when sprayed on the top of a forest, quickly was destroyed by sunlight; that very little penetrated through the forest canopy to the ground; and that if it did get into the soil, the dioxin stayed there.

But the growing cries from veterans groups that their problems were caused by agent orange prompted others to act. Seeking some hard information on the potential problems from agent orange exposure, Congress passed a law at the end of 1979 that required VA to do an epidemiology study of Vietnam veterans and to compile a complete bibliography of 2,4,5-T and dioxin health studies. VA also began an agent orange registry, an effort to identify all veterans concerned about exposure to agent orange and find out what health problems they are experiencing. Veterans' records are computerized for future work.

The biggest problem VA has had is getting the epidemiology study under way. Plans to contract out design of the study to the University of California, Los Angeles, School of Public Health were countered by a lawsuit from the National Veterans Law Center. Lewis Milford of the center says veterans did not believe VA would do an objective job in analyzing the data, because of a prejudice against blaming agent orange. Subsequently, bowing to pressure from the House Veterans Committee Subcommittee on Oversight & Investigations, as well as other Congressmen, VA transferred the whole epidemiology study to the Center for Disease Control.

Still, this did nothing for the growing number of veterans who wanted medical attention for problems they assumed were caused by the herbicide. In 1981, Congress passed the Veterans' Health Care, Training & Small Business Loan Act, which, in part, changed the rules for treatment at VA hospitals so that medical treatment for agent orange claims could be provided. Although this means most veterans who want it can get some medical attention, the question of disability compensation has not been resolved.

For veterans groups, the disability compensation issue is a top priority. According to Milford, there is enough medical evidence of a link between dioxin and cancer to allow VA to make payments. But VA claims the only confirmed medical problem is chloracne and VA has yet to grant the first disability claim for agent orange exposure.

Not that veterans haven't tried. As of May 1, 17,068 claims had been filed by persons who say they have been exposed to agent orange. Some 8400 were found to have a valid medical complaint and 1328 claims have been honored, but for reasons other than agent orange exposures. According to VA, 8617 of the claimants, when examined, had no diagnosable illness. In fact, 4102 did not even have a medical complaint, diagnosable or not.

To break this impasse, Rep. Thomas A. Daschle (D.-S.D.) has introduced legislation that would make any veterans suffering from chloracne, soft-tissue sarcoma, or the liver condition called porphyria cutanea tarda automatically eligible for compensation, whether or not any link to agent orange exposure could be made.

It is hoped that the large number of research programs now under way or starting soon will help answer all the various questions. There are at least 65 federally supported programs, expected to cost more than $100 million, in the works to study dioxin. The largest of these is the epidemiology study being done for VA by CDC. This will involve 30,000 people divided into five cohorts and will be looking for any health problems that could be associated with military service in Southeast Asia. The study is not expected to be completed until late in 1987, but other work will be finished earlier.

One of the first is the Ranch Hand study by the Air Force of about 1200 military personnel who worked spraying agent orange on South Vietnamese forests. A mortality study of these individuals has shown no evidence of a problem one way or the other, but the sample size is far too small to mean anything. More significant will be the morbidity analysis of these people that is expected this fall.

Another VA mortality study will gather data on all veterans who served in Vietnam from 1964 to 1975 and compare their cause of death with that of veterans who were not stationed there. A twins study is also part of the VA program. About 500 pairs of twins have been found, one of which served in Vietnam and the other did not. They will be given psychological, physiological, and biochemical tests to see if any health differences can be found.

VA also is utilizing the Environmental Protection Agency's National Human Adipose Tissue Study, which has been examining human fat tissue since 1972 for the presence of about 20 chemicals, but not for dioxin. VA plans to backcheck 550 samples available from men born between 1937 and 1952 who could have served in Vietnam. VA does not expect to finish this analysis until 1985. However, under the direction of Alvin R. Young, an Air Force scientist who has been involved with agent orange studies since 1969, a small pilot study of fat tissue from exposed veterans already has been done. It casts some doubt on the ability of this kind of analysis to detect any connections between illnesses and dioxin exposure.

Then there is the chloracne task force, a major effort by VA to find veterans who have the one health problem that has been confirmed as dioxin related. But to date, about 4300 claims of skin disease have been made, and only 13 could be considered service related by VA and only one of those appeared to be truly chloracne.

Another large project that has just begun at VA is a case-controlled epidemiology study for possible occurrence of soft-tissue sarcomas. These cancers, usually very rare, have been linked to dioxin exposure by two Swedish studies and some U.S. industrial experiences. About 1000 soft-tissue sarcomas recorded at the Armed Forces Institute of Pathology involve men aged 25 to 40 who might have been in Vietnam when the spraying was done. Although the protocol still is being developed, final results are expected by the end of 1985.

These federal programs are only part of the work under way. Most were started only in the past couple of years when it was realized that huge potential problems related to dioxin exposure existed. Several states have set up their own task forces to help veterans, and there are many international investigations that are trying to find a link between the phenoxy herbicides and a variety of health problems.

Dioxin history at a glance

1872	Chlorinated dioxins first synthesized by German chemists.
1948	2,4,5-T registered as a pesticide with U.S. Department of Agriculture.
1949	First industrial accident involving dioxin at Nitro, W.Va., 2,4,5-T plant.
1957	Dioxin identified as an unavoidable contaminant in 2,4,5-T.
1962–70	2,4,5-T used in defoliants in Vietnam.
1966	U.S. Department of Agriculture and Food & Drug Administration established residue tolerances for 2,4,5-T on food products.
1970	Dioxin's teratogenicity, fetotoxicity first reported in animals.
	U.S. Department of Agriculture suspends uses of 2,4,5-T that might lead to greatest human exposure.
1971	Environmental Protection Agency cancels 2,4,5-T use on most food crops.
	Stables in eastern Missouri sprayed with dioxin-contaminated oil.
1972	FDA bans use of hexachlorophene in nonprescription soaps and deodorants.
1973	Vietnamese study links higher incidences of liver cancer, abortions, and birth defects to agent orange spraying in that country.
1976	Explosion at ICMESA chemical plant in Seveso, Italy, releases several pounds of dioxin in a densely populated area
1978	EPA issues rebuttable presumption against registration for remaining uses of 2,4,5-T based on evidence that 2,4,5-T and dioxin cause cancer, birth defects, and fetal deaths.
1979	Environmental Protection Agency issues emergency suspension order to ban remaining 2,4,5-T uses except on rangeland and rice fields.
	Class action suit filed on behalf of Vietnam veterans against five U.S. chemical companies that made agent orange. Companies, in turn, file a third-party action against the U.S. government passing responsibility for alleged harm to the government for its negligent misuse of the chemicals.
1980	EPA requires advance notice of disposal of dioxin-contaminated waste.
1981	Class action suit on behalf of Vietnam veterans filed against Veterans Administration and Department of Defense.
	FDA advises people not to eat fish containing 50 ppt or more of dioxin.
1982	Extensive dioxin contamination found in eastern Missouri.
1983	EPA offers to buy the town of Times Beach, Mo.
	EPA issues proposed rule allowing disposal of dioxin-contaminated wastes only in approved landfills.

Veterans with disabilities they believe were caused by exposure to dioxin in Vietnam quickly learn that unless they get compensation from VA, no other government aid will be forthcoming. There is a strong feeling among many of these veterans that the government has a responsibility not to expose its people to hazardous substances, and that, if it does so, it should be liable. But there is a long history of the courts refusing to allow veterans to sue the government for this type of injury. So, attention has been turned to the companies that manufactured the herbicides that became agent orange.

In 1979, Victor J. Yannacone Jr., representing the survivors of a helicopter pilot who served in Vietnam, sued 11 companies for their part in exposing veterans to toxic chemicals. The number of plaintiffs has since climbed to about 9000, including 5000 veterans and 4000 survivors and children of veterans. The suit insists that the companies knew of the toxicity of agent orange's components and failed to inform the government and that, therefore, the companies should be liable for injuries caused by the herbicide and the dioxin contaminant. The suit has become lengthy, complex, and costly.

The original companies named were Dow Chemical, Monsanto, Hercules, Thompson-Hayward, Uniroyal, Diamond Shamrock, Thompson Chemical, Aggrasit, Hoffman-Taft, Riverside Chemical, and Hooker Chemical (which made the 2,4,5-T precursor 2,4,5-trichlorophenol).

Most of the companies asked U.S. Federal District Court judge George Pratt for a summary dismissal of the claims that they are responsible for any injuries, under the government contractor defense. This means that the government, as the user of the herbicides, knew as much as or more than did chemical companies about the hazards and should have used this knowledge to warn those who might be exposed. They also contend, and have proved to the judge's satisfaction, that the Department of Defense had set standards for agent orange which were met by all the companies. Two companies that have not asked for a summary judgment are Monsanto and Diamond Shamrock.

For a variety of reasons, some of the companies have been released from the suit. Those remaining are Monsanto, Diamond Shamrock, Uniroyal, Thompson-Hayward, and the largest producer, Dow. The trial had been scheduled to begin June 27, but, in a procedural move, Pratt postponed the opening until completion of the discovery process, an information gathering period that attorneys say could take another year or two.

The judge's decision to go ahead with the trial means that the companies must prove they withheld no health data from the government that would have made a difference in the spraying of the herbicide. Although there are some data in the early work on 2,4,5-T on the problems from dioxin, they are scanty. Dow, which made more than 30% of the total agent orange used in Vietnam, is sure the government had all the safety data it needed.

One of the allegations raised against the companies stems from a meeting in 1965 between Dow and other agent orange makers in which the toxicity of dioxin was discussed. Dow is supposed to have told the manufacturers they would have to do something about the levels of dioxin in agent orange, or the government would take regulatory action against the use of 2,4,5-T. Shortly after that, Dow bought a license to use a process developed by West Germany's Boehringer Ingelheim that reduced levels of dioxin in 2,4,5-T to less than 1 ppm and urged the other makers to do the same. According to Dow, some did and some did not. Whether the 1-ppm level is a safe one for dioxin is one of the questions that has not been answered, though that is just what the jury may be asked to decide at this trial.

If the companies are found liable for the injuries allegedly resulting from dioxin exposure, they can be sued in state courts by veterans or their survivors for damages. In most states, the statute of limitations will have expired for taking action against the companies and special legislation will have to be passed, as it has been in New York for instance, if the veterans are still going to be able to sue over agent orange exposures.

Just how many vets actually were exposed is a question impossible to answer. The military records are not accurate enough to tell exactly where every soldier was when spraying was done in an area. And wind drift or elapsed time before troops entered a sprayed area also would determine exposure. DOD had said early in the agent orange controversy that it kept troops out of sprayed areas for up to six weeks, but many reports show that gound troops entered some sprayed areas as early as the next day. Veterans groups say they have anecdotal evidence that planes sprayed some troops directly, or that troops had loads of agent orange dumped on them when a plane was damaged by enemy fire and had to return quickly to its base.

Despite the controversy over exposure and possible health problems, VA still holds that no long-standing health problems exist from agent orange exposure. It appears, however, that this position is being eroded by the actions of other federal agencies in response to dioxin contamination, and the difference has not been lost on veterans. Although most regulatory action against 2,4,5-T and its contaminant dioxin was not begun until after 1970—after most troop exposure in Vietnam was past—concerns about health effects of dioxin from agencies such as EPA and CDC appear to be far greater than those voiced by officials at VA. Nothing makes this clearer than the dramatic actions taken to remedy the dioxin contamination problem in Times Beach, Mo.

Times Beach has a most unenviable reputation as the town too poisoned to live in. Just a few miles west of St. Louis, its fate has been sealed as the result of some poor waste disposal practices, insufficient environmental laws in the early 1970s, and political pressures for action. Because of the contamination and the federal government's decision to buy the town, Times Beach is expected to disappear.

The story traces back to the 1960s and begins with agent orange. Hoffman-Taft, one of the original defendants in the agent orange trial, made 2,4,5-T for the Department of Defense for a while, but ceased production in 1969, about the time ecological concerns led the military to halt spraying. In November of 1969, the plant in Verona, Mo., was leased to North Eastern Pharmaceutical & Chemical Co., and then later sold to Syntex Agribusiness, which let the pharmaceutical company stay to produce hexachlorophene.

According to EPA's records, wastes from the plant were being disposed of properly by shipping them to a waste facility owned by what is now Rollins Environmental Service near Baton Rouge. But in early 1971, allegedly to save money, North Eastern contracted with a firm called Independent Petrochemical to haul away its sludge bottoms. Independent, in turn, subcontracted the job to Russell Bliss, a waste oil hauler in Missouri. The records show that Bliss hauled away 18,500 gal of waste bottoms containing dioxin from the Verona plant, which he apparently stored in waste oil tanks near Frontenac, Mo., between February and October 1971.

But Bliss used some of this contaminated waste oil to spray horse arenas in May of 1971. Three stables apparently were sprayed, and the consequences were severe. Over the next few days and weeks, hundreds of animals got sick and died, including at least 65 horses. One six-year-old child, the daughter of one of the stable owners, developed an inflamed and bleeding bladder after playing in the soil of the arena, and three other children and one adult complained of skin lesions after exposure to the stables. All the symptoms disappeared after exposure was halted and have not recurred.

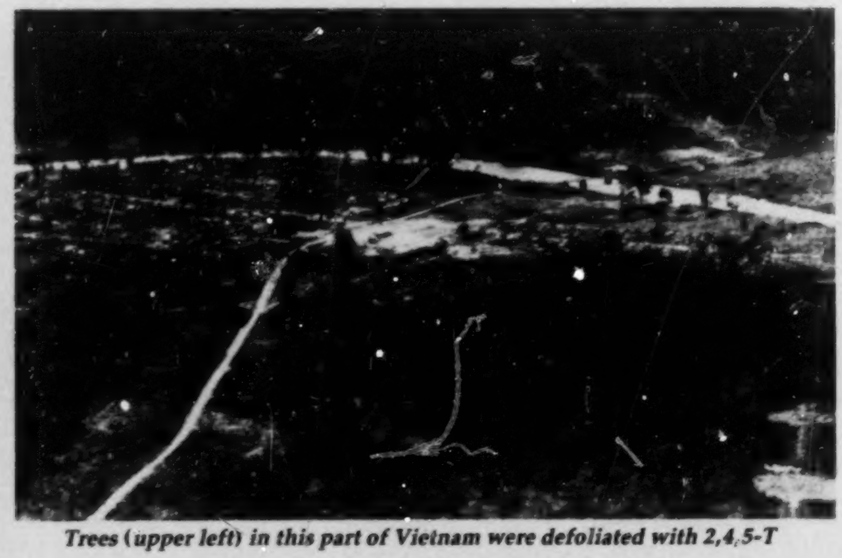
State of Missouri investigators, reasoning that something must have been in the oil that was sprayed, sent samples to CDC for analysis. The arena owner asked Bliss if anything dangerous had been in the oil and Bliss reportedly said there was not. In the meantime, the state had the arena's dirt hauled away and placed in a distant landfill. Some of it, however, was used as fill dirt for residential construction, in what has now become known as the Minker/Stout site.

CDC, with few clues to go on, took until 1974 to identify dioxin as the toxic compound in the oil. Scientists there, led by pathologist Renate Kimbrough, eventually determined that the oil was contaminated at about 33 ppm, a level far higher than any that occurred in Vietnam from agent orange. Crystals of trichlorophenol found during the soil analysis extraction led the investigators to the Hoffman-Taft plant in Verona, and the thinking was that 2,4,5-T production was the culprit. But it was then discovered that the hexachlorophene wastes made by North Eastern had been disposed of improperly.

By this time, Bliss had sprayed oil over many sites in eastern Missouri. EPA has reconstructed as much of the Bliss operation as possible and believes there were more than 150 sites sprayed with the waste oil, but how many are contaminated with dioxin won't be known until testing can be completed.

The search for contaminated areas did not begin immediately, however, as might have been expected. A large storage tank of wastes was found at the Verona site, heavily contaminated with dioxin. Levels of extracts were measured at 356 ppm by the CDC researchers. This became the primary concern because its potential for human health injury was seen as high. Syntex, which now owned the plant, had the wastes detoxified by ultraviolet treatment at its expense. It should be remembered that at that time there were no federal laws governing waste cleanup or proper disposal. The Resources Conservation & Recovery Act was not passed until 1976, and the abandoned waste cleanup law, superfund, didn't go into effect until 1981.

With no further reports of serious illnesses, the issue faded away after about 1975.



Trees (upper left) in this part of Vietnam were defoliated with 2,4,5-T

Then, in 1979, EPA's office in Kansas City received an anonymous telephone call that toxic wastes were buried on the James Denney farm, near Verona. The tip checked out, and a number of drums of dioxin-contaminated waste eventually were removed from the site. This got EPA investigators thinking.

It had been believed in the early 1970s that the half-life for degradation of dioxin in soil was less than a year, based on tests by the Air Force and U.S. Department of Agriculture. That was wrong. EPA found that waste leakage from the drums still had high concentrations of dioxin, when almost all of it should have decomposed after being buried for six or seven years. This prompted them, after much record searching, to go back to the stables that originally were sprayed and to the sites where the contaminated earth was dumped to measure present dioxin levels. The levels found were essentially as high as they had been in 1971. At the site where the soil had been used as a landfill, levels ranged from 10 ppb to 300 ppb. At the Shenandoah Stables, concentrations were still as high as 1750 ppb.

These tests began in spring of 1982, and the first data were released in August. The findings prompted a more exhaustive sampling of all the areas known to have been sprayed. By December, more than 300 samples had been analyzed and the results released. EPA had found dioxin levels of up to 300 ppb in the Times Beach area and contamination in about 14 other sites.

The news of extensive dioxin contamination in Missouri came at a critical time for the agency. EPA Administrator Anne Gorsuch Burford was under intense pressure from Congress for information relating to actions the agency had or had not taken under the superfund law, and that body was moving in early December towards finding Burford in contempt of Congress. The situation was complicated when the Meramec River, which flows by Times Beach, flooded just before Christmas 1982, and officials worried about the dioxin spreading to other communities. (Followup tests showed that the dioxin had not moved with the flood waters.)

The situation now began to get tense. Residents of the community demanded that the government buy their homes so they could move to a safe place. Some people began comparing the contamination problem at Times Beach to the situation at Love Canal in New York. Then, in early February, the EPA assistant administrator in charge of waste cleanup and superfund, Rita Lavelle, was fired by President Reagan, amid allegations she had used the superfund for political leverage in favor of Republican candidates.

Possibly pushed a little faster than she would have been otherwise, EPA Administrator Burford announced Feb. 22 that the federal government would buy up all the contaminated property in Times Beach, paying the residents a price reflecting property values before the dioxin contamination was found and before the flooding. Superfund would supply $33 million and the state of Missouri would supply $3.3 million more.

Subsequently, on April 5, EPA offered to buy a number of homes in the contaminated Minker/Stout site that had been built on dirt from the stables originally sprayed by Bliss. A third area, the Quail Run mobile home park, was found to be contaminated with up to 1100 ppb of dioxin in a sample dug out from beneath a paved road, with levels of 2 ppm inside two of the mobile homes. EPA has also offered to buy the trailer park. At this time, no other areas are being bought out.

The decision to move residents, either temporarily or permanently, is made by CDC and the Missouri Department of Public Health, on the basis of results from samples submitted by EPA. The belief that a level of 1 ppb is probably safe comes from a CDC estimate using a number of studies, and is discussed on page 48.

When EPA told the residents of Times Beach the government was going to buy their homes, the process was expected to take 60 to 90 days. Now, after three months, there is still a hangup. The federal government cannot take title to the property because the law forbids spending superfund money to clean up federally owned property. Missouri will not take title until all the residents have moved because they do not want to be expected to provide services, such as water, to the areas. There were, last month, about 50 families that were not moving, but a second flooding of the Meramec seems to have convinced them it was time to leave. Spokesmen for the Federal Emergency Management Administration, which has been on the site since the first flood in December and is responsible for dealing with the residents on the buyout, say it appears that all the former residents are leaving. In addition, an unofficial and unapproved agreement may have been reached that would permit the property to first be assigned to the city of St. Louis, so the cleanup could get started, then transferred to Missouri when that state's conditions are met. In the meantime, the residents are living elsewhere and have yet to receive the promised compensation.

As of this writing, there are 31 confirmed sites of dioxin contamination in eastern Missouri, all traceable to the spraying by Russell Bliss. Officials believe the final list could contain more than 100 sites. How many more people might have to be moved and how much it will cost is pure speculation, but the expenses can be expected to rise.

Midland, Mich., is another city that has become associated in the public mind with dioxin contamination.

The Midland connection first surfaced in the national news media last March when Rep. James H. Scheuer (D.-N.Y.) charged that he had evidence showing that then EPA acting administrator John Hernandez had intervened personally to allow Dow Chemical Co. to alter a draft EPA report on the sources and effect of dioxin in the Great Lakes region, suppressing all references to Dow's responsibility for dioxin contamination in and around its plant.

In fact Scheuer charged that owing to Hernandez's intervention, and by implication Dow's, all references to studies showing the adverse health effects of dioxin were removed from the report.

C&EN staff photo

Young: doubt cast on ability to link illness with exposure to dioxin

Testifying before Scheuer's natural resources subcommittee on March 23, Valdas Adamkus, EPA's Region V administrator, said that Dow's objections to the draft report centered on a statement that EPA concludes that Dow's Midland facility is a major, if not the only source, of dioxin contamination in the Tittabawassee and Saginaw Rivers and Saginaw Bay in Michigan. That six-line draft conclusion did not appear in the final report.

Ronald O. Kagel, director of environmental quality for Dow Chemical USA, who reviewed the report for EPA, says, emphatically, that he did not ask EPA to delete that six-line paragraph from the report. He says he did point out that "the whole paragraph was lifted out of a 1978 report and it appeared again almost word-for-word in a report written in 1979. At that time we could not dispute that and we didn't. But in 1981 there had already been an international dioxin conference. There had been many papers published supporting our theory that dioxin can be created by combustion. I said, 'Gee guys, that's a 1978 statement in a 1981 report and I really think you should change the word 'concludes' to 'speculates' because of the data that support our theory.' "

Kagel says that in making his comments he was "strictly trying to speak to the validity and technical accuracy of the report and specifically those portions that were taken out of Dow's work." Further, he says that many of the portions of the draft report released by Scheuer that were marked "cut" already had been deleted from the copy of the report he received. Others had markings indicating that somebody already had decided they should be cut.

At just about the time the charges of undue influence were being aired two Michigan environmental groups—the Foresight Society, headquartered in Lansing, and the Environmental Congress of Mid-Michigan, headquartered in Midland—filed a citizens petition with EPA asking for a full field investigation of central Michigan. They said an investigation was needed to determine the effect of the pollution caused by disposal and emissions into the air, land, and water of chemical substances that threatened the health of the residents and the integrity of the environment. At a press conference in Washington, D.C., Andrea K. Wilson, director of ECOMM, explained that "given the fact that soft- and connective-tissue cancers among white females in Midland County are four times the national average, the birth defect rate is now being re-evaluated, and Dow's own data indicate that soil samples taken at their Midland plant contain a range of TCDD (dioxin) from 0.3 ppb to 100 ppb, we feel that a full field investigation, including an epidemiological study, is warranted."

Hard on the heels of the petition came an announcement by EPA's Region V office (which covers the upper midwest) that a preliminary investigation had found more than 40 toxic chemicals, mostly in the low parts-per-billion range, in the effluent from Dow's Midland facility. Dioxin was found at levels of 50 parts per quadrillion in the effluent and at levels of 100 ppt in caged whole fish that were exposed to the effluent.

The search for dioxins in Midland may very well have been initiated by a false-positive test result. Dow periodically monitors its discharges for TCDD and on April 13, 1977, the lab reported a positive number—8 ppt with a detection limit of 3 ppt. "That got us concerned," Kagel explains, "because we had never seen dioxin before . . . but it triggered a number of things." The first thing that was done was an analysis of some fish that had been caught in the Tittabawassee River the year before during Dow's biennial river survey and placed in the freezer. Analysis of the fish showed dioxin levels ranging from nondetectable to 0.19 ppb, with a detection limit of 0.02 ppb. In May of 1977 the company collected more fish—mostly bottom feeders—from the river, analyzed them, and again found positives. Kagel points out that the state-of-art analytical method at that time allowed only the detection of 2,3,7,8-TCDD, plus 16 other tetra isomers.

After the second batch of fish was analyzed, Dow devised some experiments using caged fish to determine where the dioxin was coming from. The first shipment of fish ordered died before it got to Dow. The second batch of fish all had a fatal fish disease, commonly known as the "Ick." The third shipment from the East was found to be loaded with PCBs, which would have interfered at the time with the TCDD analysis. Finally, towards the end of 1977 Dow got a batch of usable trout and put them in cages where its effluent mixed with the river water under flowing conditions. Bioanalysis of the caged fish was completed in May 1978. Positives were found for most fish in the mixing zone. At the same time, Kagel says the fish research lab, which had been doing studies on the biomagnification of TCDD by trout, reported a biomagnification factor of 6600. Dow reported all of its findings to the State Department of Natural Resources in June of 1978. In July, the company met with state representatives and made a commitment to find the source of the dioxins.

Agent orange had far less dioxin than earlier 2,4,5-T herbicides used in Vietnam war

Code name	Herbicide	Quantity, gal	Period of use	2,3,7,8-TCDD, ppm
Orange	2,4-D; 2,4,5-T	10,646,000	1965–70	1.98
White	2,4-D; picloram	5,633,000	1965–71	—
Blue	Cacodylic acid	1,150,000	1962–71	—
Purple	2,4-D; 2,4,5-T	145,000	1962–65	32.8[a]
Pink	2,4,5-T	123,000	1962–65	65.6
Green	2,4,5-T	8,200	1962–65	65.6
TOTAL		17,705,200		

a Assumed level from one known and four probable samples of purple. Note: Pink and green levels are twice that of purple because they were full-strength 2,4,5-T. Sources: Proceedings from 2nd Continuing Education Conference on Herbicide Orange, May 1980; and Air Force OEHL technical report on toxicology, fate, and risk from agent orange and dioxin, October 1978

The first thing Dow did, Kagel says, was to look at its own internal waste streams, where it might expect to find dioxins, and didn't find anything that could be considered significant. Then, he says, "Quite by accident two of the chemists in the lab went up to the second floor to get a control sample of dust off a bookshelf. They analyzed that dust and found it contained all the dioxins—the tetras, the heptas, the hexas, the octas. We said, 'My God, we've been looking for a waterborne source and we know that . . . the second floor has never been under water. So it's got to be from somewhere else that's airborne."

That, he explains, is when "we started looking around the division at dirt samples and seemed to find more dioxins as we got closer to our incinerator and power plants." Thus was Dow's combustion theory born.

The company dispatched scientists to several cities to collect soil samples around municipal incinerators and powerhouses. In almost every case they found dioxin, although not necessarily 2,3,7,8-TCDD. They analyzed the carbon soot inside mufflers collected in Detroit and found dioxins. They also found 100 ppt of 2,3,7,8-TCDD in the soot from a fireplace, which happened to belong to Kagel.

According to Kagel, the formation of dioxins is maximized and its destruction minimized when the temperature is low, below 750 °C. At

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POSSIBLE TOXIC CONTAMINATION

Science News photo

Road going through Times Beach, Mo., is blocked by sign warning of dioxin

temperatures above 1000 °C just the opposite occurs—formation is minimized and destruction maximized. Thus, municipal incinerators could be expected to produce more dioxins than industrial incinerators, which burn at 1000 °C, because the municipal facilities operate at generally lower temperatures.

Dow Chemical researchers sample Tittabawassee River for dioxin near the company's Midland, Mich., plant

While it was doing this work Dow also was perfecting its analytical techniques, Kagel says, using a mixture of three different methods during the course of study. The first separated out 2,3,7,8-TCDD plus 16 other tetra isomers; the second, 2,3,7,8-TCDD plus 11 others; and the third 2,3,7,8-TCDD plus two other isomers. Then in late 1978 a technique was developed that isolated all 22 tetra isomers.

Since 1979 Dow has done several other studies. Having, as Kagel says, "made the comment that we thought that dioxin had been around since the advent of fire" and figuring that wood was one of the earliest fuels, a study was done of residential woodburning stoves in Minnesota, New Hampshire, Oregon, and Michigan's upper peninsula. The source of the wood for each stove was carefully documented to make sure it had never been sprayed, never treated with pentachlorophenol, Kagel says. But in each case some dioxins were found in the soot from the stoves.

As Kagel points out, one of the components of wood is lignin, a phenolic material. There is also a natural chlorine content in wood which will vary from 14 to 84 ppm. "Remember," he says, "we're talking about reactions that occur with a yield of $10^{-10}\%$. These are trace reactions, and 14 ppm, when you're looking at a millionth of a millionth—a ppt—is a lot of stuff. It's the same with coal, which actually has a much higher chlorine content than wood, and is nothing more than a whole mess of ring compounds of one sort or another. So the basic building blocks are there."

"This is as close as we can come," he says, "to confirming the de novo principle, that dioxin is made from carbon, hydrogen, oxygen, and chlorine. Nobody has done a definitive experiment on that that I know of. But the preponderance of evidence right now would support the fact that you can get dioxins formed at very low levels in the combustion processes from common fuels."

If that is true it would go some way towards explaining the results of a recent study which shows dioxin contamination in fish in many rivers in Michigan. The fish were collected from 19 Michigan rivers, plus Saginaw Bay and Lake Erie by DNR. Their skinless fillets were analyzed by Swiastolov Kadzmar, a graduate student working under Matthew J. Zabic, professor of entomology and assistant director of Michigan State University's pesticide research center. Thirty-four of the 62 fish analyzed had no detectable levels of dioxin. Levels of 2,3,7,8-TCDD in the other fish samples ranged from a low of 17 ppt, with a detection limit of 12 ppt, to a high of 586 ppt, with a detection limit of 81 ppt. Many of the positive samples came from fish taken from waters that had no connection with the Tittabawassee rivershed and therefore they could not have been contaminated by Dow's effluent, though the samples did come from rivers in industrialized areas.

Typically, Kagel says, dioxin is very tightly bound to fly ash, as it is to soil. To remove dioxin from fly ash one has to do exhaustive benzene or toluene soxhlet extractions for 24 hours. "It's very tightly held," he says, "so the question is how does it get off the fly ash and into the fish?" Dow has been involved with EPA's Duluth, Minn., lab in a joint study designed to answer that question. Duluth supplied some carp fingerlings, Kagel explains, "which we put into a fish tank with some municipal fly ash of which the 2,3,7,8-TCDD content was about 160 ppt. That represented about 0.48% of the total tetra isomers, all of which were present. After 30 days in the tank the fish were taken out and analyzed and 84% of what was found in the fish was 2,3,7,8-TCDD."

Kagel theorizes: "There's some weird mechanism in the fish—that was phase two of our study, to try and find out what that mechanism is—that makes them selectively accumulate 2,3,7,8-TCDD, or, the other way around, there is some mechanism whereby they break down or metabolize the other isomers. That was a preliminary experiment and we were going on to controlled experiments when all of this started and we never got back to it. . . . I sure would like to get an answer."

So would everybody else. Dow says that it has no manufacturing operation anywhere in the U.S., including Midland, that has any 2,3,7,8-TCDD associated with it. But EPA's Region V office in Chicago isn't so sure. On April 11 it asked Dow for any and all process- and waste-related information the company might have pertaining to dioxins. Dow delivered the first set of data—2000 pages worth—on May 12. The company said it took 26 employees, 13 of them working full time, to compile that information and it is still collecting data.

Among the data submitted were the results of a new soil analysis conducted by Dow, repeating the analysis done in 1978, except this time the analytical technique was isomer specific. Five soil samples collected inside the plant site showed levels of 2,3,7,8-TCDD of 0.08, 0.38, 2.04, 0.018, and 0.02 ppb. The levels in two samples from Midland were 0.0016 and 0.0072 ppb; Chicago, 0.0010 and 0.0042 ppb; Lansing, Mich., 0.0030 ppb and not detected; and Detroit, 0.0036 and 0.0021 ppb. "There is no health hazard in Michigan because of dioxin in the dirt or in Chicago. Not at the levels we find it," Kagel says.

Midland's mayor Joseph Mann agrees. "So what if we've got 7 ppt in the soil here. Being bound the way it is how do you get to it? How do you come in contact with it? How do you assimilate it?" He points out that if the exposure were causing harm it would manifest itself somehow. But he says studies by the State Department of Public Health have shown that "the overall cancer rate in Mid-

Few regulations aim specifically at dioxin

Despite all the problems—medical, political, and social—associated with dioxin, it remains a remarkably unregulated compound. Early concerns focused on exposure to the dioxin-contaminated herbicide 2,4,5-T; only recently has dioxin itself been regulated.

In 1970 a Congressional hearing took place and the National Institute of Environmental Health Sciences announced a study that showed birth defects in animals that were exposed to 2,4,5-T containing low levels of dioxin. This prompted the U.S. Department of Agriculture to disallow most uses of the compound, permitting use only on forests, rights-of-way, open rangeland, and rice fields. In addition, a voluntary agreement by 2,4,5-T makers limited dioxin concentrations to less than 0.1 ppm.

The ball was passed to the new Environmental Protection Agency, which continued its investigations and soon moved to further limit the herbicide's use. In 1973, EPA set up the Dioxin Monitoring Program to monitor residues of dioxin in human and environmental samples. EPA attempted to cancel all uses of herbicides that were derived from 2,4,5-trichlorophenol in that year but eventually had to cancel the proceedings because the analytical methods necessary to determine low levels of dioxin were not available. The agency began a rebuttable presumption against registration process on 2,4,5-T in 1978.

Then in May 1979, on the basis of heavily criticized studies linking the spraying of forest areas with 2,4,5-T to a number of miscarriages among women in Oregon, EPA issued an emergency suspension that allowed the herbicide to be used just on rangeland and rice fields because EPA saw little risk of human exposure there.

The hearings on cancellation of 2,4,5-T have dragged on. They currently are suspended while EPA and the chemical manufacturers try to reach some kind of agreement, possibly on permitting some use of the herbicide if dioxin levels in it can be kept very low.

But other tools have passed into EPA's hands for regulating dioxin. On May 19, 1980, EPA published a rule under the Toxic Substances Control Act that requires any person intending to dispose of wastes that contain dioxin, or even of substances produced on equipment that previously was used to make 2,4,5-trichlorophenol, to notify EPA 60 days in advance of such disposal. That notification must include details on the amount being disposed of and the method to be used.

Just recently, the agency proposed a regulation for treating dioxin-contaminated waste under the Resource Conservation & Recovery Act. This would permit disposal of dioxin-contaminated waste only at facilities that are fully licensed by EPA. The agency says potential problems might arise if disposal is allowed at unpermitted landfills or in incinerators that might not be working properly. This rule, if adopted, would supersede the 60-day notification rule.

The other area in which EPA is moving forward is dioxin contamination of water. EPA presently is monitoring effluents from chemical plants to determine if dioxin is present and, if so, at what concentration. These data could be used in preparation of a water quality criteria document. This would give manufacturers an idea of what EPA thinks is a safe level for dioxin in water and probably would presage further regulation of dioxin, under either the Clean Water Act or TSCA. (Because dioxin is a priority water pollutant, some states have regulations that require no detectable levels in plant effluents.)

The only other significant action taken on dioxin is by the Food & Drug Administration. A series of recommendations (not regulations) by FDA in 1981 advised people not to eat fish with dioxin levels greater than 50 ppt, but that fish with less than 25 ppt of dioxin were okay to eat. Because these are not regulations, an FDA spokesman points out that if the levels do rise above 50 ppt, the agency cannot take any action to remove the product.

Thus, aside from the restrictions on the use of 2,4,5-T (because of its dioxin contamination) and the current 60-day notification rule for waste disposal, dioxin is not specifically regulated by the federal government.

land is low—below the national average, below the state average, and below the average for the surrounding region." He says there was a soft-tissue sarcoma in women that was higher than normal. "There was one case in the 1950s, five cases in the 1960s, and eight cases in the 1970s. This was a matter of concern to the county health department, the state health department, and certainly to us," Mann says. The State Health Department conducted a study and released its results on May 4. And according to Mann "could not ascribe any particular causes to the rate of increase. There was no commonality between the cases that could be found; although the department felt there must have been a commonality, they certainly couldn't say that it was dioxin."

The department did recommend development of a registry of persons most likely to be exposed to dioxins as evidenced by their occupations, fish consumption patterns, or location of residence. Such a cohort of people, it said, could serve as a framework for possible future epidemiologic studies.

Meanwhile, Midland's attitude to the dioxin issue is expressed in a variety of ways. Mann says that "the perception within the community is that there's nothing out of the ordinary, nothing dangerous." But he adds, "That's not the perception if you get more than 100 miles away from here and have gotten most of your information from the news media."

Then there are the retirees from and employees of Dow who come into Rep. Donald J. Albosta's (D.-Mich.) local office and who, says office manager Pat Casey, feel as if the criticism is being directed at them. "Their feelings, and I think their beliefs, are that they worked for a high-class company that spent a lot of bucks on environmental concerns and research. Dow has always had a very aggressive in-plant safety program. So the employees don't feel there is any justification for the insinuation they pick up that Dow has done something wrong."

C&EN staff photos

Kagel: dioxin dust on a bookshelf

City manager Clifford Miles thinks that one of the reasons for the very low level of concern in the city, and one he personally subscribes to, "is that the people who have done the testing, the measuring, the toxicology and epidemiology studies are all Midland people. They all live here with their families. It isn't some outsiders coming in and saying either it's safe or unsafe. It is Midland people that are doing these things and they have significant reputations not only in Midland but worldwide." Certainly no one is going to stay here if they know their family is in jeopardy, he says. Miles explains that over the years, because of Dow's environment and safety record, "people have built up a wealth of confidence in that corporation that could not be bought." And he says, "They [Dow] have done everything they can and should have done to alert the public, the media, the state and federal government."

Mann: nothing out of the ordinary

Some people aren't so confident. As Dianne Herbert, one of the leaders of ECOMM, sees it, "Dioxin is a sexy issue that has gotten the attention of the media, but it certainly isn't the only environmental or health problem in Michigan." She also thinks it's good that the attention of EPA is focused on Midland. However, she notes the city itself is fighting any investigation. "They naturally want to get the focus off," she says. "Their strategy is let's spread it out and say, 'Oh yes, dioxin needs to be looked at, but all over the country.' There are problems—people don't want to move to Midland, people have called and asked, 'What kind of place is it?' Maybe the problems should have been taken care of earlier on. They accumulated until they all blew up and that's too bad. I'm from Michigan and I like living here. I don't want to give up my house. I don't want to move."

Herbert says she understands the reluctance of any community to believe that there is something wrong or that the company that many of them work for has done something that is illegal or bad for their health. "The average person you talk to," she says, "will say that Dow has been good to us and I would never disagree with that. For a community this size to have its own symphony, a beautiful center for the arts—that is very unusual. But I don't think that gives them the right to do what they want with the air, and the water, and the land. The bottom line is that in this community Dow decides what is safe and what is dangerous. They make those decisions for people and I think that people should be allowed to make their own decisions."

Others are seeking further information. That was the purpose of a late May forum on dioxins organized by the Midland sections of the American Chemical Society, American Institute of Chemical Engineers, and Sigma Xi.

At the forum, which about 500 people attended, a panel of five technical experts on dioxin issues answered questions from five local citizens—none of whom worked for Dow—and the audience.

According to Susan Butts, a senior research chemist at Dow and an organizer of the forum, its impetus came from the fact that "we were aware that a lot of studies had been done on various aspects of the dioxin problem, but we hadn't really heard very much about the results of those studies. Our concern was really in trying to hear a more detailed explanation of the sitution, in terms that would be understandable not only to scientists but to the general public." In putting the panel together, she says, "We tried to be sure that we fairly represented all points of view. We did rather heavily weight it towards people with a biomedical background, because we thought most of the questions from the audience would concern human health problems. And most of them did. There were a lot of questions about the toxicity of dioxins, about the meaning of toxicity, and about how dioxins would be rated relative to other health hazards."

For her part, Butts says she never had a personal concern about her own health, but she did want to know where Midland stood in relation to other places in the U.S. that have problems with dioxin contamination. "I felt quite reassured," she says, "by what we were told by the panel members. There were some minor disagreements about interpretation of data. But, if I were going to try to summarize what the panel said, it would be that they didn't feel that there was any significant health problem in Midland. But until we know more about the situation they would like to continue monitoring health in Midland to make sure."

In fact just about everybody seems to agree that what is needed is continued monitoring and more study, preferably not just in Midland, nor even just Michigan, but nationwide. Rep. Albosta is seeking funding for just such a study. He feels that a number of questions need to be answered. Questions such as: How pervasive is dioxin? At what concentration is it present in the environment? Where is it coming from? What are safe levels? Are dioxins bioaccumulating in the environment? Is that a problem? And, finally, are national standards needed to deal with the problem?

The study as now planned would be run by the Region V office. A prototype study costing $2 million to $3 million would first be done in Michigan. That study then would be expanded to a national level at a total cost of about $12 million. According to Richard Powers of DNR's toxic chemical evaluation section, the Michigan part of the study, as tentatively planned, would consist of a study in the vicinity of Midland to determine the extent of contamination in that area. This would mean sampling soil, air emissions, and water effluents from the plant site, and river sediments. The second component of the study would be monitoring fish, including game fish and bottom-feeding carp, in 15 Michigan rivers for dioxin contamination.

As part of the national study, air and soil sampling and possibly fish monitoring would be done at other sites, perhaps in Michigan, perhaps in Region V, or perhaps somewhere else in the country. Powers says, "It doesn't make any difference to us where they're done, as long as they are done. We feel it is necessary to have comparability studies in other areas of the country, both areas that would be expected to be contaminated and others which should be relatively clean."

Protocols for the study are being developed, but actual work is pretty much on hold because everything is contingent on getting federal funding. The House Appropriations Committee has included $5 million in EPA's fiscal 1984 funding bill for nationwide dioxin studies—$1 million for R&D and $4 million for monitoring studies in Michigan and Missouri as well as other places. The Senate Appropriations Committee has not yet made a decision. EPA's new administrator, William D. Ruckelshaus, is expected to ask Congress for more money for the agency both in this and the next fiscal year and reportedly has expressed his support for a national dioxin study.

Although everybody, including Dow, supports a study, not everybody is happy about what is being planned. As Mann puts it, "First you say there's a ticking time bomb, a life-threatening situation, and then you do these studies—the results of which won't be out for two or three years. What we need is a reasonable amount of analysis in a reasonable amount of time, primarily to reassure people outside this community that it isn't as bad as had been pictured."

Along the same lines, the Midland City Council, three of whose five members, as well as Mann, work for Dow, passed a resolution expressing its support of scientific studies on exposure levels and effects of dioxin on the environment and the public health as long as they weren't limited to Michigan, but also expressing the council's feeling that $12 million was just too much.

Further study is quite probably the proper response to the levels of dioxin contamination that have been found in Michigan. And, although EPA appeared to rush into Missouri in an attempt to improve its public image when everything the agency did was being looked at with cynical eyes, hindsight may show the decision to be justifiable and prudent. Other human exposures to dioxin, such as those of soldiers in Vietnam or the people in Seveso, Italy, in 1976, involved considerably less dioxin than those of the Times Beach residents.

In Vietnam, for instance, the Air Force's Young calculates that the level of dioxin in the soil would have been 0.017 ppb, 20,000 times less than the 300 ppb found in Missouri. That assumes that agent orange, with an average dioxin concentration of 2 ppb, is sprayed at a rate of 3 gal per acre and that all the dioxin falls right to the forest floor (although studies found that only about 7% of the agent orange penetrated the forest canopy).

Similar types of exposure comparisons can be made for the residents of Seveso, leading to the conclusion that the Missouri experience may represent the largest, long-term exposure to dioxins that humans have endured. If dioxin is the hazard that some believe, then the costs of moving entire towns probably are not greater than the risks of letting people continue to live there. □

Dioxin's Human Toxicity Is Most Difficult Problem

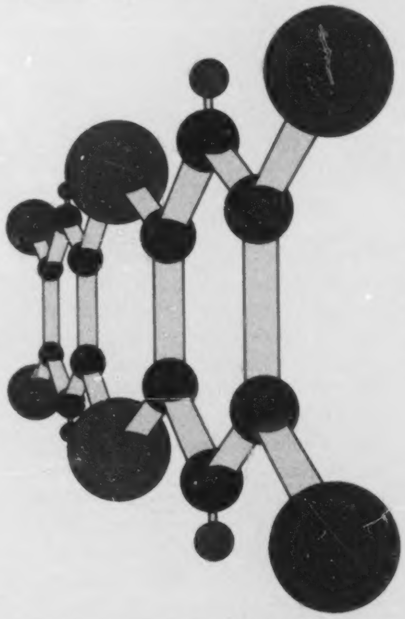
Dioxin is extremely toxic to certain animals, but scientists are only beginning to understand the nature of its toxicity and exactly what it does to humans

Rebecca L. Rawls, C&EN Washington

Of all the questions that surround dioxin, probably the most important one, and one of the most difficult to answer, is: What is its effect on human health? Although its presence in the environment still would cause problems if it were harmful only to horses or guinea pigs or some other animals, it is the possibility that dioxin may be very hazardous to people that is behind most efforts to understand how the compound behaves in the environment and to learn how to deal with it.

That dioxin is extremely toxic to certain animals, causes many different toxic effects in a wide range of animal species, and is harmful to humans when they are exposed to relatively large amounts of it are facts that are well established. But even after more than a decade of intensive study, scientists are only beginning to understand how dioxin causes its toxic effects, and the key question of whether it causes any long-term, irreversible health effects in humans remains unanswered.

The widely made claim that dioxin is one of the deadliest substances known, or that it is the deadliest man-made substance, is based on its extreme toxicity in guinea pigs. As little as 0.6 μg per kg of body weight given orally will kill half of the male guinea pigs that receive the dose. Illness occurs immediately and death within about a week. Mole for mole, this makes dioxin some 2000 times more toxic than strychnine, for example, in the mouse. Only a handful of substances are known to be more toxic than dioxin is in guinea pigs.



But dioxin is much less toxic to mice than it is to guinea pigs. In fact, one of the striking features of dioxin's toxicity in animals is that the lethal dose varies so much from one species to another. The guinea pig, the most sensitive animal yet tested, is 5000 to 10,000 times more sensitive than the hamster, the least sensitive animal yet tested. Rabbits, mice, and monkeys cluster somewhere in the middle—roughly 200 times less sensitive than guinea pigs and 50 times more sensitive than hamsters.

Dioxins are not the only compounds that show this range of sensitivities from one animal species to another. Such a pattern is characteristic of several halogenated aromatic compounds, including chlorinated dibenzofurans and chlorinated and brominated biphenyls. The fact that all of these compounds have closely related chemical structures leads some toxicologists to study them as a class and has led to promising work that is beginning to unravel how these compounds cause their toxic effects.

Dioxins and these other halogenated aromatic hydrocarbons cause many different effects simultaneously in treated animals, and the relative importance of these effects varies from species to species. Thus, dioxin appears to kill rats by causing severe liver damage, but in the guinea pig the liver lesions seem less serious and the animal appears to die from a starvationlike wasting away of the entire animal. Both the liver lesions and the wasting away occur to some degree in all of the animals that have been studied; only the relative importance of these effects varies. Similarly, all species studied lose lymphoid tissue, particularly from the thymus, and become more sensitive to infections. However, it usually is not the infection that kills them, and putting treated animals in a germ-free environment will not save them.

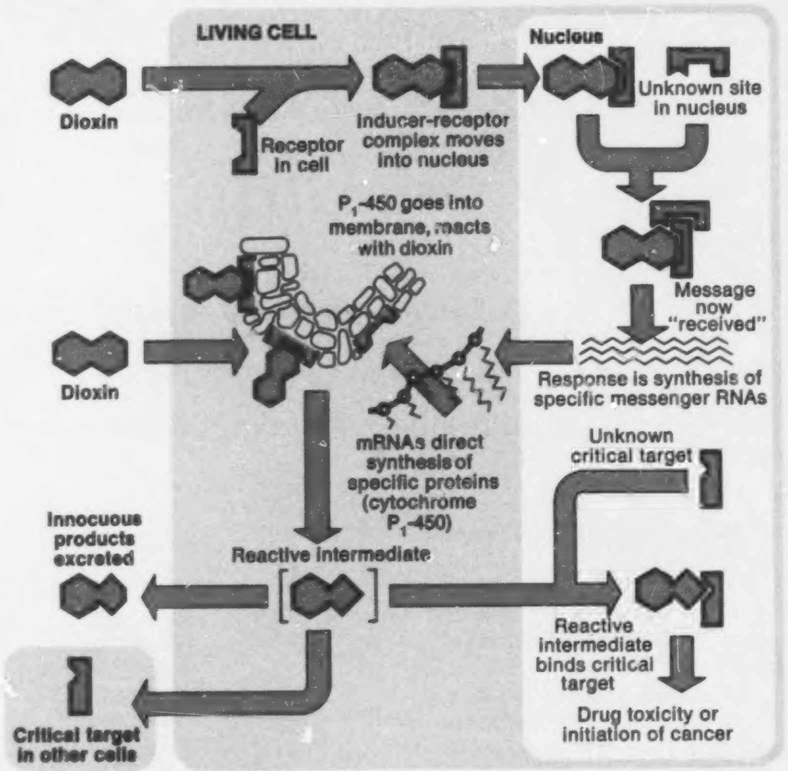
Not all effects are found in all animals. Chloracne, a skin lesion that is the most characteristic and frequently observed effect of chlorinated aromatic hydrocarbons on humans, does not occur in guinea pigs, hamsters, or some mice. Hairless mice, however, do develop a chloracnelike skin condition when exposed to dioxin, and so do rhesus monkeys and rabbits. Cattle develop skin lesions, too, but they are quite different from the kind that are seen in humans, monkeys, and rabbits.

In addition to these acute, or immediate, effects, dioxin produces at least two types of serious long-term effects in some laboratory animals—reproductive effects and cancer. As is true for nearly all long-term health effects studies, most of the work on dioxin effects has been done on rats and mice.

Because dioxin is so acutely toxic to many adult laboratory animals it is difficult to examine its teratogenic and reproductive effects. However, several studies in mice have found cleft palates and kidney abnormalities in offspring of animals fed 1 to 3 ng of dioxin per kg of body weight per day. Rat studies do not show birth defects. Instead, dioxin kills the developing fetus or embryo at levels similar to those that cause birth defects in mice.

Small-scale studies on monkeys show that dioxin is fetotoxic to these animals as well. Pathologist James P. Allen of the University of Wisconsin medical school has found that breeding female monkeys fed 1.7 ng of dioxin per kg of body weight per day for two years aborted four of seven pregnancies. In a study by Wilber P. McNulty of the Oregon Regional Primate Research Center, pregnant monkeys were given doses ranging from 9.5 to 240 ng per kg of body weight per day for three weeks during their gestation period. The two animals in the highest dose group died from their dioxin exposure. They also aborted. At the level of 48 ng per kg per day, the mothers were only slightly sick, but three of the four animals in the study aborted. At the lowest level, the mothers ap-

Researchers seek to explain dioxin's effects on cellular biology


LIVING CELL
Nucleus
Dioxin
Receptor in cell
Inducer-receptor complex moves into nucleus
Unknown site in nucleus
P_1-450 goes into membrane, reacts with dioxin
Message now "received"
Dioxin
Response is synthesis of specific messenger RNAs
mRNAs direct synthesis of specific proteins (cytochrome P_1-450)
Unknown critical target
Innocuous products excreted
Reactive intermediate
Reactive intermediate binds critical target
Drug toxicity or initiation of cancer
Critical target in other cells

If the exquisite sensitivity of some, but not all, animals to dioxin is a frustration to many researchers, it is a source of delight to one group: the molecular pharmacologists. It is not an accident that some cells are incredibly sensitive to dioxin, and by exploiting the differences between dioxin response in different types of cells, these scientists have a probe for examining some of the very intricate inner workings of cells.

"If morphine addiction weren't a problem, morphine would still be an interesting drug for what it can tell us about enkephalins. That's the way we feel about dioxin," explains one researcher in the field.

A consistent picture of some of dioxin's interactions with animal cells is emerging from work going on in several laboratories including those of Alan Poland and Joyce C. Knutson at the University of Wisconsin; Robert A. Neal and William Greenlee at the Chemical Industry Institute of Toxicology, Research Triangle Park, N.C.; and Daniel W. Nebert at the National Institutes of Health, Bethesda, Md. Though this work does not explain all of dioxin's toxic effects, it does begin to make some sense out of one of the more puzzling aspects of dioxin's toxicity—the great range in acute toxicities found in different animal species.

According to this picture, dioxin is only one example of a larger class of halogenated aromatic hydrocarbons. All of these materials bind to the same receptor, a soluble protein within the cytoplasm of susceptible cells. The binding site of this receptor has been quite well mapped out. Substrates need to be generally planar and pretty well fill a rectangle 10 Å long and 3 Å wide. Highly polarized groups, like chlorine atoms, need to be in at least three of the four corners and nowhere else in the molecule.

These requirements fit dioxin exactly, but other molecules like chlorinated dibenzofurans or brominated biphenyls also can be accommodated in this attachment site and induce dioxinlike toxicity in animals. The site's geometry goes a long way toward explaining why the 2,3,7,8-tetrachloro isomer of dioxin is the most toxic, since this is the one that has all four corner positions of the

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molecule and no others occupied by chlorine atoms.

Once bound, the dioxin-protein complex moves into the nucleus where it turns on the activity of a specific set of genes called the *Ah* (for aromatic hydrocarbon) locus. These genes, in turn, produce messenger RNAs that direct the synthesis of a family of proteins called cytochrome P-450s within the cell. Cytochrome P-450s are enzymes whose function is to react with foreign molecules like dioxin so they can be metabolized and eventually excreted from the body.

To this point, the system seems to be a beneficial one for the cell. Unfortunately, among the metabolites of dioxin as it is processed by the cytochrome P-450 system there seems to be a substance that is toxic. Inadvertently, a system that was intended to rid the body of foreign chemicals by making them easier to excrete has converted a fairly innocuous substance into a toxic one.

It now seems apparent that this whole process is controlled genetically at two points, at least. One of these is the *Ah* locus, which controls the amount and structure of the receptor protein within the cell and turns on production of the cytochrome P-450s. Experiments in mice have shown that genetically inbred strains that do not have the *Ah* locus are not susceptible to some of dioxin's toxic effects. But the *Ah* locus alone is not enough to produce toxicity, as is shown by experiments in which cytochrome activity is turned on by the presence of dioxin though there is no toxic response. Poland and Knutson have found that chloracne can be produced by dioxin in a certain strain of hairless mice even though mice generally do not show this reaction to dioxin. It is not the lack of hair itself that is responsible for chloracne in these mice, they find. Instead, some part of the genetic locus that is responsible for the hairless trait in mice is also necessary to produce the chloracne response.

It is interesting to speculate on why animals have evolved an elaborate system for dealing with foreign chemicals and why it sometimes goes awry with molecules like dioxin, making them more, rather than less, toxic to cells. One model that satisfies pharmacologists considers dioxin to be a foreign molecule that just happens to fit into a receptor and turn on a cell system originally designed to respond to an endogenous molecule and that once had some useful purpose. Such a model makes dioxin analogous to morphine, which stimulates a natural pain-killing system in place of the body's own trigger molecule—enkephalin. But to have dioxin fit a similar pattern, there would need to be a structurally related compound naturally present, at least on occasion, in the body. There also would need to be some advantage in certain circumstances to triggering the ordinarily toxic responses that the body makes to dioxin.

The body's response to dioxin, theoretically, at least, might sometimes be useful. Properly controlled, the ability to stimulate cell proliferation, for example, could lead to useful growth or repair of tissues instead of cancer. So far, however, a natural dioxinlike molecule has not been found in animal tissue.

Useful as this picture of dioxin's role in cellular biology is, it does not explain all the chemical's toxic effects. Indeed, the model purposely focuses on those effects of dioxin that vary most widely from species to species. But dioxin has other effects, like the wasting away of tissue, that appear to be common to all animal species examined. Tissue wastage is not a trivial effect of dioxin; it is probably the cause of death in the very sensitive guinea pig.

British studies in the mid-1970s showed that animals recovering from dioxin exposure had unexpectedly high numbers of cells with more than one nucleus, suggesting that perhaps cell membrane proliferation had been impaired by dioxin exposure. This work might provide a clue to the wasting effect dioxin has on animals.

Certain experiments indicate that some of dioxin's effects are brought about by such incredibly small doses of the compound that the number of molecules in the dose is too small to account for the observed effect—at least in terms of a receptor binding model. In these cases, at least, there seems to be some sort of chain reaction that magnifies the effect of a small dose of dioxin.

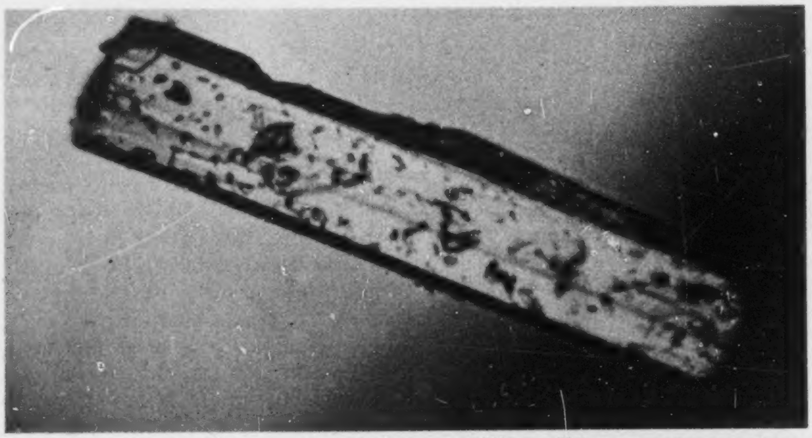
peared to be healthy, and their abortion rate, one in four, was about the same as that of the nontreated group, where three abortions occurred in 11 pregnancies.

Clearly, dioxin is fetotoxic to some animals and causes birth defects in others. However, its high toxicity to the mother means that the range in which it causes toxic effects on the fetus but not on the mother is very narrow. Thus, some toxicologists classify dioxin as a weak teratogen. Ironically, the fact that humans appear to be less sensitive to the acute effects of dioxin means that it could be a more potent teratogen for them than it seems to be for laboratory animals.

Several independent tests in rats or mice show that dioxin is an extremely potent carcinogen in these animals. Richard J. Kociba of Dow Chemical's Toxicology Research Laboratory found that female rats fed 10 or 100 ng of dioxin per kg of body weight developed a greatly increased number of liver tumors. At the higher dose level, both male and female rats developed increased numbers of tumors in the mouth, nose, and lungs, as well as in the liver. Nearly half the female rats in the higher exposure group developed tumors. When the data on female rats are used to calculate the potency of dioxin as a carcinogen, dioxin comes out to be about three times as potent a carcinogen as aflatoxin B_1, which is one of the most potent carcinogens known. Equally significant, however, according to Kociba, is the finding that at doses below 10 ng even the female rats showed no increased incidence of tumors in this study. He considers this evidence that there is a no-effect level for dioxin-induced cancers in the rat.

A similar study conducted for the National Cancer Institute by researchers at Illinois Institute of Technology found statistically significant increases in thyroid tumors in male rats at all doses studied and an increase in subcutaneous tissue fibronomas in male rats at the highest dose level (0.5 mg per kg of body weight per week). In female rats, the study found an increase in tumors of the liver, subcutaneous tissue, and the brain at this same dose level.

Besides these two studies there



2,3,7,8-Tetrachlorodibenzo-p-dioxin is a crystalline solid at room temperature

have been about a half-dozen others that provide some evidence that dioxin is a carcinogen in rats and mice. Although some of these other studies have methodological flaws that make them less definitive than either the Kociba or the NCI study, a panel evaluating the carcinogenic potential of dioxin for the Environmental Protection Agency in 1981 concluded that collectively these studies support the conclusions of the Kociba and NCI studies and provide strong evidence that dioxin is a potent carcinogen in animals.

Most chemical carcinogens tend to attack specific organs and produce large increases in one particular type of tumor. Dioxin produces many different tumor types in different organs, which has led some researchers to speculate that it may be a promoter, rather than an initiator, of carcinogenicity. In other words, dioxin might not actually be responsible for tumor formation, but might instead work in some way that makes the cells more receptive to tumor formation if some other activating agent is present to begin the process.

Several studies have been designed to consider this possibility. One, by Henry C. Pitot and coworkers at the University of Wisconsin, examined the effect of dioxin on rats that already had been exposed to another carcinogen, diethylnitrosamine. Animals receiving both substances had a greatly increased incidence of liver tumors compared to those that received dioxin alone, suggesting that dioxin can be a promoter of carcinogenicity. However, in a series of studies by D. L. Berry of Oak Ridge National Laboratory's biological division, dioxin neither initiated nor promoted carcinogenicity when administered along with polycyclic aromatic hydrocarbon carcinogens. Instead, it appeared to block the effect of these carcinogens in mice.

Dioxin's chemical structure suggests that it could intercalate into DNA as several carcinogen initiators are believed to do. However, experiments designed to show such interaction have, so far, given only negative results, possibly because the molecule is so highly reactive with cellular proteins that it is not actually available to react with DNA. The highest estimate of the degree of covalent bonding of dioxin to rat liver DNA in vivo is less than 1 molecule of dioxin per 10^{11} nucleotides, or four to six orders of magnitude less than what is found for most chemical carcinogens.

As is almost always the case in dioxin research, the interpretation given to these and other animal test findings depends very much on who is making the interpretation. To Dow Chemical's director of biomedical research, James H. Saunders, the animal data show that dioxin is a promoter, but not an initiator, of carcinogenicity in animals. The EPA carcinogen assessment group, on the other hand, says that since promoters generally do not produce the large increases in tumor formation when given alone that dioxin produces, dioxin should be regarded as both an initiator and a promoter of carcinogenicity.

The differences in interpretation given to the animal data on dioxin toxicity, however, pale almost to insignificance when compared with the differences that arise from examining the human data. All of the data on humans come from people who somehow have been inadvertently exposed to dioxin, always in combination with many other halogenated aromatic chemicals, and often in situations where the exposure occurred years or even decades before anyone realized that it might have important health consequences. As a result, such basic information as exactly who was exposed to dioxin at what concentration and for how long often can only be estimated.

As with animal studies, the acute effects of dioxin exposure are the easiest to establish. Most of these data come from industrial accidents in which a fairly small number of workers received a single exposure to dioxin. There have been more than 800 reported cases of this type of exposure. In addition, some 37,000 people may have been exposed to measurable amounts of dioxin when a 2,4,5-trichlorophenol-manufacturing reaction went out of control at the ICMESA chemical plant near Seveso in northern Italy. More than 500 residents of nearby towns were treated for what were presumed to be toxic effects following the accident. Thus, Seveso stands out as the single most important industrial accident in terms of the information it can provide about the human health effects of dioxin.

By far the most significant finding from the Seveso data and those of the other industrial accidents is that humans are much less sensitive to the immediate toxic effects of dioxin than are guinea pigs. So far, there has been no clear case of a human death caused by dioxin exposure, discounting voluntary abortions that were performed following the Seveso accident. There are, however, many well-documented toxic effects.

The bellwether of these acute effects is thought by many epidemiologists to be chloracne, a skin condition in which circular patches of blackheads and pale yellow cysts develop on the face and, in more severe cases, on other parts of the body.

More than 800 workers have been exposed to dioxin in industrial accidents

Date	Workers exposed	Location of accident	Remarks
1949	250	Monsanto's 2,4,5-trichlorophenol plant at Nitro, W.Va.	122 cases of chloracne being studied; so far, 32 deaths vs. 46.4 expected; no excess deaths from malignant neoplasms or circulatory disease; studies continue
1953	75	BASF's 2,4,5-trichlorophenol plant at Ludwigshafen, West Germany	55 cases of chloracne, 42 severe; 17 deaths so far vs. 11 to 25 expected (4 gastrointestinal cancers and 2 oat-cell lung cancers); most common injuries were impaired senses and liver damage; studies continue
1956	?	Rhône-Poulenc's 2,4,5-trichlorophenol plant in Grenoble, France	17 cases of chloracne, also elevated lipid and cholesterol levels in blood
1963	106	NV Philips' 2,4,5-T plant in Amsterdam, the Netherlands	44 chloracne cases (42 severe), of whom 21 also had internal damage or central nervous system disturbances; 8 deaths so far (6 possible myocardial infarctions); some symptoms of fatigue; full report planned
1964	61	Dow Chemical's 2,4,5-trichlorophenol plant at Midland, Mich.	49 cases of chloracne; deaths so far 4 vs. 7.8 expected, 3 cancer deaths vs. 1.5 expected, one a soft-tissue sarcoma; studies continue
1965–69	78	Continuing leaks in 2,4,5-trichlorophenol processing area of Spolana's 2,4,5-T plant near Prague, Czechoslovakia	78 cases of chloracne; so far 5 deaths; many of the 50 workers studied for more than 10 years have hypertension, elevated blood levels of lipid and cholesterol, prediabetes; significant amounts of severe liver and neurologic damage; studies continue
1966	?	Rhône-Poulenc's 2,4,5-trichlorophenol plant in Grenoble, France	21 chloracne cases
1968	90	Coalite & Chemical's 2,4,5-trichlorophenol plant in Derbyshire, U.K.	79 chloracne cases; so far 1 death from coronary thrombosis; cohort study planned; company refuses to divulge any more information
1976	156[a]	ICMESA's 2,4,5-trichlorophenol plant at Seveso, Italy	Workers are being studied along with exposed townspeople; more than 500 residents treated for presumed toxic symptoms; 134 confirmed chloracne cases; overall mortality rate normal so far; studies continue

[a] In addition to these ICMESA workers, some 37,000 residents of nearby towns also were exposed to dioxin in this incident. **Source:** American Medical Association study, 1981

By itself, chloracne is not considered a serious condition, although it can be disfiguring while it persists. After mild exposure it usually clears up in a few months, but for more severe cases it can last for as long as 15 years. Hundreds of cases of chloracne have been seen after industrial accidents, including 134 confirmed cases at Seveso. Most of the Seveso cases were elementary school children.

In addition to chloracne, other symptoms develop with increasing dioxin exposure. These include a general sense of fatigue or malaise, disturbances in the responses of the peripheral nervous system such as a measurable slowing down of the speed at which nerve impulses travel through the limbs, and liver toxicity including changes in many enzyme levels and in some cases enlargement of the liver. Industrial exposure data seem to indicate that these conditions generally disappear after a few years and the experience at Seveso seems largely to confirm these findings.

Of more concern at Seveso and elsewhere are the possible chronic effects, especially those that might be caused by lower-level exposures like those experienced by soldiers serving in Vietnam during the 1960s when dioxin-contaminated herbicides were used there, by workers in plants making dioxin-contaminated products and by their families, by citizens living in communities like Times Beach, Mo., with its unexpectedly high levels of dioxin in the soil, or even by the population of areas where 2,4,5-T or other dioxin-contaminated herbicides may have been used during the long period when such use was allowed in the U.S. Potentially exposed people in these categories easily number in the hundreds of thousands.

Fortunately, the evidence for chronic health effects in humans is much less substantial than for acute effects. There are, in fact, distinguished researchers who argue that no chronic human health effects of dioxin have been proved. Stated just that way, probably few epidemiologists would disagree. But there are studies that suggest long-term health problems and literally thousands of anecdotal incidents that link dioxin exposure to health problems.

Probably the most highly respected studies suggesting a link between dioxin exposure and long-term health effects are those of Swedish epidemiologist Lennart Hardell at University Hospital, Umea. Hardell's work links use of dioxin-contaminated phenoxy herbicides with an increased incidence of soft-tissue sarcomas, a rare form of cancer that affects muscle, nerve, and fat tissue. In two studies he finds a five- to six-fold increase in the incidence of this type of tumor in people who have used phenoxy herbicides compared with his control group.

Dow scientists, and others, have criticized the Hardell studies on several counts. For one thing, the determination of whether or not subjects were exposed to phenoxy herbicides was made by asking them or their relatives whether they could remember any exposure. This is not a very accurate method, and, according to Dow's Saunders, people in the exposed group more frequently were asked if they could recall herbicide use than were people in the control group. Another point that concerns epidemiologists is that the people in one study apparently were exposed to products that contained much lower levels of dioxin than those in the other study, but both groups showed the same degree of increased risk. Such data suggest that some factor other than dioxin might be responsible for the elevated cancer risk. Finally, there is a problem with the identification of the tumors as soft-tissue sarcomas. Because this is a rare cancer type, most pathologists have very little experience in identifying it. It is, to some degree, a classification that is used for tumors that don't fit into other, more clearly definable categories. Hardell relied on medical records to identify the sarcomas; he did not examine the tissues himself.

Nevertheless, the Hardell studies cause concern, and that concern is increased by early results from studies of Monsanto and Dow Chemical workers who were exposed to dioxin in separate industrial accidents in 1949 and 1964. Altogether, 182 workers from these two incidents are being monitored. By 1979, 36 of these workers had died, fewer than the 54 that would have been expected based on national mortality statistics. However, three of the people who died had soft-tissue sarcomas, and a fourth who has died since 1979, also had soft-tissue sarcoma. For a form of cancer with a predicted incidence of less than 1% among cancer victims, finding four in such a small sample is unexpected. "It certainly raises the question as to whether there is something there," says Dow's Saunders. "But, [although] it is statistically significant, there is always that uncertainty of what would have been the luck of the draw in a sample this small."

Examination of death certificates and hospital records for Midland County, Michigan, where Dow's plant is located, also shows an elevated incidence of soft- and connective-tissue cancers among women in the period from 1960 to 1978. Exactly what this finding means is unclear, according to a report from the Michigan Department of Public Health released last month.

"It is not my judgment at this point that there is a clear link [between dioxin exposure and incidence of soft-tissue sarcomas in humans]," Saunders says. "It is a question that merits further study. We do not see sarcomas in animals [exposed to dioxin]," he points out. "What we see are carcinomas, [which are] epidermally derived tissue tumors, particularly liver cancer, as in the rat. Furthermore, when one sees cancer in rats, one sees it at a level 10 times that which produces obvious toxicity in the animal. In other words, when one produces liver cancer with dioxin in the rat, one has a very sick rat who is very sick for a long time and then develops cancer." This is very different from the humans who develop soft-tissue sarcomas, he maintains.

Other studies do not show an association between phenoxy herbicide use and increased incidence of soft-tissue sarcoma. One study that examined the relationship among people in various occupations in the state of Washington and incidence of soft-tissue sarcoma found that the occupations with the greatest number of soft-tissue sarcomas, as determined by data on death certificates, were marine engineers and bankers, groups that would not be expected to have had particularly high exposure to dioxins. Allan H. Smith and associates at the school of medicine at Wellington Hospital, New Zealand, are in the midst of a study of the incidence of soft-tissue sarcomas among herbicide applicators in New Zealand. Because New Zealand requires herbicide applicators to be registered, records of exposure to phenoxy herbicides are particularly good in that country. In a preliminary report presented in 1982, Smith had not found any instances of soft-tissue sarcomas in this group.

The Veterans Administration is putting together a study designed to see if Vietnam veterans, who may have been exposed to dioxin through the use of agent orange in Vietnam, have an increased incidence of soft-tissue sarcomas. The study, being directed by epidemiologist Han K. Kang, will use data from the Armed Forces Institute of Pathology, which is, in effect, the U.S. center for the evaluation of soft-tissue sarcomas. The institute has on file some 8500 cases of soft-tissue sarcoma, or roughly one quarter to one third of all the cases ever reported in the U.S. The study will examine tumors reported to the institute between 1975 and 1980 to see if Vietnam veterans are overrepresented in this group. A final report of the study is expected in 1985.

Dioxin's lethality compared to other poisons

Substance	Animal	Minimum lethal dose (moles per kg body weight)
Botulinum toxin A	Mouse	3.3×10^{-17}
Tetanus toxin	Mouse	1.0×10^{-15}
Diphtheria toxin	Mouse	4.2×10^{-12}
2,3,7,8-TCDD	Guinea pig	3.1×10^{-9}
Bufotoxin	Cat	5.2×10^{-7}
Curare	Mouse	7.2×10^{-7}
Strychnine	Mouse	1.5×10^{-6}
Muscarin	Cat	5.2×10^{-6}
Diisopropylfluorophosphate	Mouse	1.6×10^{-5}
Sodium cyanide	Mouse	2.0×10^{-4}

Source: EPA

One potential problem with this study is that the latency period for soft-tissue sarcomas is thought to be about 15 years. Since dioxin contamination of Vietnam occurred in the 1960s, the time period may be too short to evaluate properly what effect dioxin use in Vietnam had on development of this type of tumor. However, by 1980, reports of Hardell's findings were causing pathologists to look more closely for soft-tissue sarcomas, and the researchers chose a 1980 cutoff to remove this bias from their study.

In addition to cancer, animal studies raise concern about the possibility of fetotoxicity in humans exposed to dioxin. Several studies and many anecdotal reports of such effects in humans have appeared. By and large, however, these studies have methodological flaws that bring their findings into question.

One of the most important of these studies, at least politically, involved a group of nine women in the Alsea

Basin in Oregon who lived near forests that were sprayed seasonally with dioxin-contaminated herbicides. The women were concerned that 13 miscarriages in their group in the mid-1970s seemed to be linked chronologically with the spraying of the forests. The Environmental Protection Agency conducted two studies, one examining just these nine women and a larger one looking at miscarriage rates in that part of Oregon. Although the first study did not find a statistical relationship between the women's miscarriages and the spraying, the second study did. This study played a major role in EPA's decision in 1979 to issue an emergency suspension against many uses of the dioxin-contaminated herbicide 2,4,5-T.

However, the study did not stand up to critical evaluation. A team of University of Oregon researchers in 1979 panned the study on practically all counts. Among other things, they found that the study did not have a proper control, its data both on miscarriages and on 2,4,5-T spraying were inaccurate, there were many other factors besides 2,4,5-T spraying that varied among the three groups examined, and the variations in the levels of miscarriages reported by the study were well within expected ranges.

Dioxin's lethal dose varies in different species

Animal	LD_{50} (µg per kg body weight)
Guinea pig	1
Rat (male)	22
Rat (female)	45
Monkey	<70
Rabbit	115
Mouse	114
Dog	>300
Bullfrog	>500
Hamster	5000

Source: Poland and Knutson, *Annual Review of Pharmacology & Toxicology*, 1982

Poorly designed or conducted studies seem to plague the effort to find out if dioxin causes human reproductive effects. At least two Vietnamese studies, one from the early 1970s and one announced earlier this year, claim to show a substantial increase in these conditions as well as cancer following the spraying of agent orange in that country. However, western epidemiologists are uncomfortable with the lack of data on normal rates for miscarriage and birth defects in the Vietnamese population. They also question the way in which the Vietnamese data were collected.

Similarly, data from Seveso seem to show an increase in both the number of spontaneous abortions and in the number of birth defects in the period immediately following the ICMESA accident. However, there is so much uncertainty about what levels should be considered normal for this population that it is unlikely that the question of whether the Seveso incident caused increases in these conditions will ever be resolved. Epidemiologists who think there may be an association between dioxin exposure and these effects call the Seveso data "suggestive" of an effect; those who think that these effects probably don't occur in humans point out that the levels were well within the normal range for western countries.

Dioxin has different effects in different animals

Symptom	Monkey	Guinea pig	Cow	Rat	Mouse	Rabbit	Chicken	Hamster
Abnormal cell proliferations or organ enlargement								
Gastric mucosa	++	0	+	0	0			0
Intestinal mucosa	+							++
Urinary tract	++	++	++	0	0			
Bile duct/gall bladder	++		+		++			
Lung				++				
Skin	++		a	0	0	++		
Atrophy or decreased cell proliferation								
Thymus	+	+	+	+	+		+	+
Bone marrow	+	+			+		+	
Testicle	+	+		+	+		+	
Other effects								
Liver lesions	+	0		++	+	++	+	+
Edema	+	0		0	+		++	+

Note: 0 indicates lesion not observed; + indicates lesion observed (number of pluses notes severity). a Skin lesions are observed in cattle, but they are different from the lesions seen in other species. **Source:** Poland and Knutson, *Annual Review of Pharmacology & Toxicology*, 1982

There exist, in addition, several studies that do not show any increase in miscarriages or birth defects among populations that might be considered at risk because of their dioxin exposure. Studies of Dow Chemical and Monsanto chemical workers and their wives show no increase in either of these factors. So does a study released last month by the Michigan Department of Public Health that examined the rate of birth defects in Midland County, where Dow made 2,4,5-trichlorophenol until 1979.

A recently released study of the reproductive effects of dioxins on the families of Australian soldiers who fought in Vietnam during the period when agent orange was being sprayed there shows no increase in miscarriages or birth defects among these families. The study is highly praised scientifically, but there is uncertainty as to whether these Australian soldiers received very much exposure to dioxin while they were in Vietnam. Consequently, this negative finding does little to allay the fears of those who think dioxin may cause human reproductive problems.

So the overall picture that has emerged so far shows dioxin as extremely toxic and carcinogenic based on animal studies, but the picture is much less clear about human health effects. Human studies are continuing—the U.S. government is spending more than $100 million on several epidemiologic studies of the health consequences of possible dioxin exposure to veterans who served in Vietnam, and major studies also are under way in Australia, New Zealand, Finland, Sweden, the U.K.,

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and many other countries. Most of the U.S. studies are scheduled to be completed by 1987, but already epidemiologists wonder whether uncertainties about exposure levels and questions about what other factors may have accompanied dioxin exposure will weaken the value of the studies' findings.

Not surprisingly, current assessments of the risk dioxin poses to human health vary greatly depending on which of the available data seem most important to the assessor. A reasoned argument can be made that the animal data show, in addition to severe toxic effects in certain species, that great variability can be expected from one animal species to another and that the available human data suggest that humans are among the least sensitive of animals to dioxin's effects. That interpretation is not incompatible with any of the human epidemiologic data published so far, and it may turn out to be the true picture of dioxin's hazard.

Most toxicologists, however, are much more conservative in their risk assessment. This means that, in the absence of stronger evidence to the contrary than has been seen so far for dioxin, a proven risk in animals is considered to be a potential risk in humans, and a substance that causes acute effects in humans is viewed with suspicion as a possible cause of chronic effects.

It is in this spirit of prudence that EPA views the cancer risk of dioxins in humans. "Carcinogenic responses have been induced in mice and rats at very low levels of [dioxin]," EPA's carcinogen assessment group concluded in 1981. "In addition, dioxin has been shown to be a potent cancer promoter. These results, together with the strongly suggestive evidence in epidemiologic studies, constitute substantial evidence that dioxin is likely to be a human carcinogen."

C&EN staff photo

Saunders: experimental uncertainty

Such assumptions are only the first step in coming up with an estimate of human risk in any particular situation, however. At a site like Times Beach, Mo., explains Renate D. Kimbrough, medical officer for the center for environmental health at the Center for Disease Control, assessors also need to know how much dioxin people exposed to contaminated soil are likely to absorb. That's not well established, she says, although one study at the University of California has shown that when dioxin is on the skin, 1 to 10% will be absorbed. Dioxin binds to soil, so probably less is absorbed from there than if the dioxin were applied directly to the skin. One Seveso study found that about 1% of soil dioxin was absorbed, but the sample size was small and the results are inconclusive.

Besides, Kimbrough points out, absorption may not be the only route of exposure. Some contaminated dust may float in the air and enter the lungs, and some may be eaten, especially by children.

Given all these uncertainties, CDC still came up with a level of soil contamination that it believed was low enough to pose no threat to the health of Times Beach residents. "We decided to take one increased incidence in a million as a reasonable risk," Kimbrough says, and to base their hazard assessment on studies of birth defects caused by dioxin in rhesus monkeys. Toxicologists usually allow a factor of 100 below the no-effect level in an animal study as a margin of safety when extrapolating to humans, she explains. However, in the case of the monkey study, the animals had limited, not lifetime, exposure to dioxin, so the standard safety factor was increased to 1000. The resultant calculations come up with 1 ppb as a level likely to be safe. A similar calculation based on the carcinogenicity of dioxin in rats gives about the same level, Kimbrough says.

Such values ought not to be taken as a national standard for dioxin in the soil, she cautions. CDC will be reviewing its assessment procedure with outside consultants to see if it is possible to come up with national standards for soil contamination. Even if such standards can be drawn up, there is not likely to be a single level that will be appropriate for all sites, she points out. For example, in desert areas, where very few people live, soil probably could contain higher levels of dioxin before the total health risk became equivalent to the one at Times Beach. On the other hand, data from the U.S. Department of Agriculture indicate that grazing livestock easily pick up dioxin from the soil, probably because they eat so much soil as they graze. People who eat the meat from these animals or drink their milk have an additional route of exposure to dioxin. Thus, soil levels in areas where animals graze must be lower to obtain an equivalent risk.

Is it really appropriate to base human health risk estimates on the experience of laboratory animals when limited data suggest that humans may be a good deal less susceptible to dioxin than some laboratory animals are? Kimbrough thinks it is. There is very little information on what chronic exposure levels have been in workplaces, she points out, so it is difficult to know how much weight to place on long-term studies of workers' health that seem to find no ill effects. Also, except for Seveso, there is very little information on the effects of dioxin on women or children. And even at Seveso, soil dioxin levels in areas where people were allowed to return to their homes were generally in the parts-per-billion range or lower. Animal studies show that dioxin's effects vary greatly from one species to another. In some cases the effects have even been pinned down to the presence of a particular genetic locus within a species. But the human population is genetically very diverse, so that even if many people are not susceptible to the hazards of dioxin, there may be subpopulations who face a substantial risk. ◻

JUNE 13, 1983

CHEMICAL & ENGINEERING

NEWS

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Facts & Figures for the chemical industry

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CHEMICAL & ENGINEERING NEWS

JUNE 13, 1983

News of the Week

- **New photochemical process that uses a laser may be useful in medicine and dentistry.** Page 4
- **NRC committee recommends developing policy for transporting hazardous materials.** Page 5
- **Chemistry as separate high school subject may have to be dropped to make way for more biology and physics, study concludes.** Page 5
- **Polypeptide isolated from rat brains is linked to benzodiazepine receptors.** Page 6
- **Transfer of biotechnology abroad can do without stiffer controls, study group postulates.** Page 6

Business

Aspartame's high price tag impedes extensive use; production of amino acid precursors is one of several hindrances. **Page 8**

Government

Technology assessment by governments viewed as an ongoing process with consequences for society, OECD study shows. **Page 13**

Science

Alternative study to Global 2000 Report reverses claims for future trends; economists and others see improvement. **Page 18**

Conductive polymer's colors, indicative of various oxidation states, may be useful as basis in display devices. **Page 21**

Books

Scientists who try to stretch the facts, and their motivations for doing so, are examined in "Betrayers of the Truth" by William Broad and Nicholas Wade. **Page 68**

Meetings

Washington, D.C., will host the ACS annual meeting; 516 technical sessions will be offered, along with special events, awards, and a variety of social activities. **Page 73**

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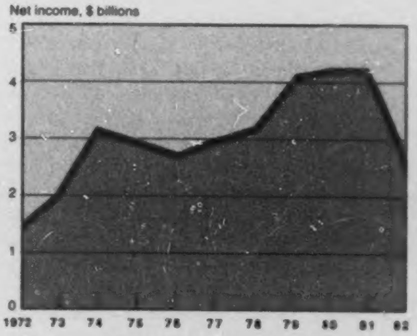


Facts & Figures

Lean years follow relatively prosperous ones for the chemical industry, as revealed in C&EN's latest annual compilation of statistics. **Page 23**

Facts & Figures
for the chemical industry

It has been three lean years in a row for the U.S. chemical industry, hard on the heels of four relatively fat ones. And in many ways, last year was the leanest of the three. Industry executives have been practically unanimous in viewing the year as probably the most problem wracked within memory.

With demand from some of the industry's most important customers in a severe slump, chemical companies were forced to cut back their operations drastically. Production of chemicals and synthetic materials, which had largely recovered from the sharp but relatively brief recession of 1980, began to fall again during the second half of 1981, hit bottom last summer, but remained depressed throughout the year. For 1982 as a whole, consequently, output averaged 14% lower than in 1981 and 16% under the peak year of 1979. Particularly hard hit were basic organic chemicals (down 19% last year) and man-made fibers (down 20%); fiber output in 1982 was 25% less than in 1979.

Nor was depressed output solely a U.S. phenomenon. Across the world, chemical operations were in the doldrums—or worse—as economic problems gripped both industrialized and developing nations.

In the U.S., at least, 1983 has brought some long-awaited signs of recovery. The rebound has been moderate so far, to be sure, and plants continue to operate at unsatisfactory levels well below those of early 1981, let alone 1979. Nevertheless, nearly everyone in the industry is convinced that the corner has been turned and that 1983 will register a marked improvement over last year.

On the following pages, C&EN's annual Facts & Figures issue presents the statistics that measure the chemical industry's recent performance. It brings together data from a diverse number of sources, including government agencies, trade associations, international organizations, and individual chemical companies. These data have been used, in addition, to develop an array of other statistics that indicate growth rates, provide analytical comparisons, and otherwise interpret the industry's record.

Facts & Figures at a glance

Section One: Production
Output of almost all chemicals and related products slumped during 1982. Production of such bellwether inorganics as sulfuric acid, chlorine and caustic soda, and ammonia, for example, had not been so low in nearly a decade or more. Olefin output was at the lowest level since 1976. Man-made fibers were more depressed than at any time since 1975. Plastics held up better than other major segments of the industry; nevertheless, production of thermoplastics last year was slightly less than in 1978 and 11% below 1979's peak. **Page 28**

Section Two: Finance
Sales of major chemical companies fell last year for the first time since 1975, largely because demand dried up but also because prices for industrial chemicals and plastics declined as well. Profits, meanwhile, were under heavy pressure, collapsing to the lowest level in nine years. Poor profitability and stagnant markets have led the industry to slash its outlays for new plant and equipment. But R&D budgets continue to rise, albeit at a more moderate rate than during the past few years. **Page 35**

Section Three: Efficiency
Productivity slumped in the chemical industry last year, driving unit labor costs up sharply as a result. One reason probably was the very low level of capacity utilization, well below that of the preceding year, throughout 1982. **Page 49**

Section Four: Employment
The chemical industry's workforce declined steadily all through 1982, hitting bottom by year's end at the lowest level since late 1976. Most major companies cut down on the numbers of workers on their rolls, some to levels lower than their employment 10 years ago. **Page 52**

Section Five: Foreign trade
Worldwide recession caused world trade in chemicals to drop 11% in dollar volume, an unprecedented second decline in a row. For the second consecutive year, too, the favorable trade balance long enjoyed by U.S. chemical producers narrowed. Weak overseas markets and a stronger U.S. dollar resulted in a 6% drop in U.S. exports, and imports were practically unchanged from the year before. Even so, the U.S. managed to hang onto its overall share of the world chemical market. **Page 54**

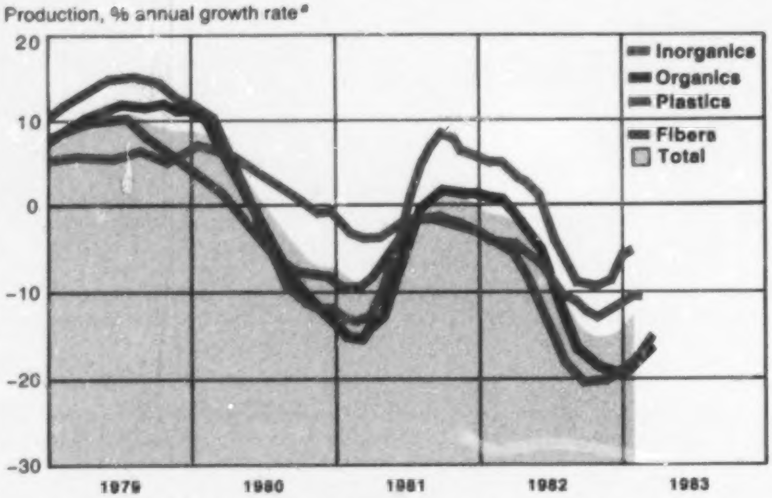
Section Six: Foreign chemical industries
Business was poor for chemical producers just about everywhere abroad last year. Production stumbled in most of the countries of Western Europe, with the industry in West Germany being hardest hit. Operations similarly stagnated in Japan, with petrochemicals particularly racked with problems. In Eastern Europe, growth was slow and failed to match official targets. In Canada, chemical producers, hit by reduced demand in both domestic and overseas markets and by high feedstock costs, saw their earnings dwindle. And in Mexico, output dropped after several years of rapid growth. **Page 56**

1 Production by the U.S. Chemical Industry

Output down for chemicals, related products

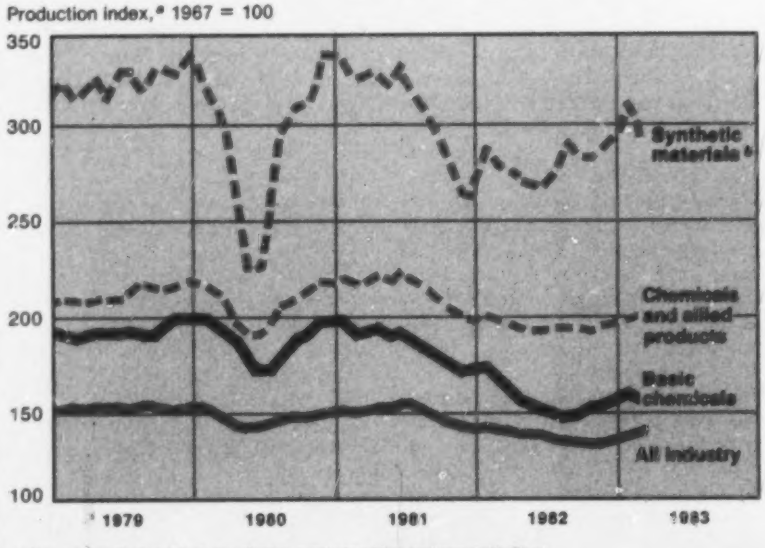
jd11, udc7, ff1a, c&en

Severe slump in chemical output eased by end of 1982



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Chemical output in 1982 sank to low level of 1980



a Seasonally adjusted. b Includes plastics, synthetic rubber, and man-made fibers.
Source: Federal Reserve Board

Output of U.S. chemical plants dropped in 1982 to the lowest levels since the recession of 1980. However, unlike the earlier steep but short-lived slump, output remained depressed throughout the year. Not until year-end was there any sign of recovery, and for 1982 as a whole production of chemicals and allied products was 9% less than in 1981.

Although production was off throughout the chemical industry, basic chemicals were hit hardest. Output of organic chemicals was down almost 20% in 1982 and inorganics and fertilizer materials fared almost as badly.

Among synthetic materials, production of man-made fibers sank 20% from the levels of 1981. The largest-volume fiber, polyester, was off 24%, dragging down the entire sector. Olefin fibers were the top performers, with only an 8% production decline.

After a small gain in 1981, output of plastics returned to the depressed levels of 1980. Only high-density polyethylene showed an increase in production. Low-density polyethylene didn't do too badly, with only a 2% drop. But other large-volume thermoplastic and thermosetting resins showed substantial declines.

The bright spot among chemical products was the drug industry, where production managed to hold its own at 1981 levels. And soaps and toiletries were off only 3%. In contrast, paints were down 9%, the second year of decline in a row. Agricultural chemicals production sank 14% after nine years of healthy growth.

Inorganic chemicals used in fertilizers—like ammonia, phosphoric acid, and sulfuric acid—all plummeted from output levels that were already lower than those of 1980. The poor performance reflects a sharp drop in both exports and U.S. consumption of fertilizer in 1982.

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TOP 50 CHEMICALS: Last year's sharp drop sank output beneath 1977's level

Rank			Production				Average annual growth			
			Billions of lb		Common units[b]					
1982	1981[a]		1982	1981	1982	1981	1981–82	1980–81	1977–82	1972–82
1	1	**Sulfuric acid**	64.61	81.35	32,304 tt	40,675 tt	−20.6%	−8.1%	−3.4%	0.4%
2	5	**Nitrogen**	35.07	35.51	484 bcf	490 bcf	−1.2	2.3	7.9	9.6
3	2	**Ammonia**	30.98	38.08	15,488 tt	19,038 tt	−18.6	0.0	−2.5	0.2
4	4	**Oxygen**	29.66	35.68	358 bcf	431 bcf	−17.0	0.0	−1.9	0.1
5	3	**Lime**[c]	28.40	37.78	14,202 tt	18,890 tt	−24.8	6.8	−5.6	−3.0
6	6	**Ethylene**	24.68	29.42	24,683 mp	29,418 mp	−16.2	2.6	−0.6	1.7
7	8	**Sodium hydroxide**	18.28	20.83	9,141 tt	10,414 tt	−12.2	−10.4	−3.5	−1.1
8	7	**Chlorine**	18.27	21.12	9,136 tt	10,560 tt	−13.5	−7.5	−2.9	−0.8
9	9	**Phosphoric acid**	17.05	19.83	8,523 tt	9,914 tt	−14.0	−9.4	−1.0	2.4
10	12	**Sodium carbonate**[d]	15.79	16.56	7,896 tt	8,281 tt	−4.7	0.1	−0.5	0.6
11	10	**Nitric acid**	15.22	18.08	7,608 tt	9,039 tt	−15.7	3.5	−0.9	−0.5
12	11	**Ammonium nitrate**[e]	14.66	17.58	7,331 tt	8,791 tt	−16.6	−3.7	0.4	0.7
13	14	**Propylene**	12.29	13.48	12,290 mp	13,482 mp	−8.8	−1.4	−1.6	3.8
14	13	**Urea**[f]	11.84	16.21	5,918 tt	8,103 tt	−27.0	3.5	5.9	5.6
15	15	**Ethylene dichloride**	9.99	9.97	9,985 mp	9,974 mp	0.2	−10.2	−1.9	2.5
16	16	**Benzene**	7.90	9.63	1,073 mg	1,308 mg	−18.0	−35.0	−6.9	−1.5
17	24	**Toluene**[g]	7.67	6.18	1,057 mg	852 mg	24.1	−16.2	−0.2	1.4
18	18	**Carbon dioxide**[h]	7.38	7.96	3,688 tt	3,982 tt	−7.4	7.0	5.5	8.6
19	17	**Methanol**	7.26	8.58	7,265 mp	8,577 mp	−15.5	19.9	2.3	1.8
20	19	**Ethylbenzene**	6.67	7.81	6,674 mp	7,812 mp	−14.6	2.2	−4.3	1.6
21	20	**Vinyl chloride**	6.50	6.87	6,495 mp	6,874 mp	−5.4	6.3	1.6	2.5
22	21	**Styrene**	5.93	6.68	5,928 mp	6,680 mp	−11.3	−2.6	−2.9	−0.1
23	22	**Xylene**	5.29	6.35	735 mg	882 mg	−16.7	−3.0	−2.6	−0.1
24	26	**Ethylene oxide**	5.00	5.11	5,000 mp	5,109 mp	−2.1	−2.1	2.7	2.4
25	23	**Terephthalic acid**[i]	4.97	6.23	4,974 mp	6,234 mp	−20.2	3.0	−1.7	5.3
26	27	**Hydrochloric acid**	4.97	5.00	2,483 tt	2,501 tt	−0.7	−13.6	−1.8	0.6
27	25	**Formaldehyde**[j]	4.69	5.72	4,691 mp	5,721 mp	−18.2	3.0	−5.0	−1.9
28	30	**Ethylene glycol**	4.30	4.14	4,295 mp	4,142 mp	3.7	−5.6	3.2	1.3
29	29	**Ammonium sulfate**	3.57	4.22	1,785 tt	2,111 tt	−15.4	−1.2	−3.9	−0.4
30	28	***p*-Xylene**	2.93	4.53	2,926 mp	4,532 mp	−35.4	6.9	−1.6	2.8
31	32	**Acetic acid**	2.75	3.07	2,751 mp	3,074 mp	−10.4	3.3	1.4	2.1
32	31	**Cumene**	2.68	3.31	2,678 mp	3,309 mp	−18.7	−4.3	0.3	1.6
33	35	**Aluminum sulfate**	2.37	2.59	1,186 tt	1,294 tt	−8.3	0.6	−5.5	0.0
34	34	**Carbon black**	2.29	2.73	2,290 mp	2,730 mp	−16.1	7.2	−7.2	−3.2
35	36	**Phenol**[k]	2.14	2.58	2,136 mp	2,578 mp	−17.4	0.4	−1.8	1.1
36	39	**Acrylonitrile**	2.04	2.00	2,041 mp	1,996 mp	2.3	9.1	4.4	6.2
37	40	**Vinyl acetate**	1.88	1.94	1,876 mp	1,936 mp	−3.1	0.7	3.4	4.5
38	33	**Butadiene**[l]	1.83	2.99	1,825 mp	2,986 mp	−38.8	6.7	−10.9	−6.4
39	37	**Sodium sulfate**[m]	1.79	2.33	893 tt	1,164 tt	−23.2	2.2	−5.7	−3.9
40	38	**Acetone**	1.76	2.14	1,757 mp	2,144 mp	−18.0	3.8	−4.6	0.1
41	41	**Calcium chloride**[n]	1.75	1.83	875 tt	917 tt	−4.4	13.1	−2.0	−2.9
42	43	**Propylene oxide**	1.48	1.73	1,477 mp	1,734 mp	−14.8	−1.9	−4.6	−0.3
43	44	**Isopropyl alcohol**	1.31	1.67	1,310 mp	1,669 mp	−22.2	−9.1	−7.2	−3.1
44	46	**Sodium silicate**	1.30	1.48	650 tt	738 tt	−12.2	−6.0	−3.1	−0.2
45	45	**Titanium dioxide**	1.27	1.52	635 tt	761 tt	−16.6	−3.3	−1.6	−0.9
46	42	**Cyclohexane**	1.27	1.82	1,272 mp	1,819 mp	−30.2	−7.4	−10.7	−5.7
47	47	**Sodium tripolyphosphate**	1.26	1.39	632 tt	696 tt	−9.2	−11.8	−2.5	−4.8
48	49	**Adipic acid**	1.20	1.21	1,197 mp	1,210 mp	−1.1	0.8	−4.9	−2.1
49	48	**Acetic anhydride**	1.06	1.25	1,061 mp	1,248 mp	−15.0	−15.0	−6.7	−3.9
50	50	**Ethanol**	1.02	1.32	1,022 mp	1,317 mp	−22.7	−9.2	−5.3	−5.8
		TOTAL ORGANICS IN TOP 50	**150.33**	**173.94**			**−13.6%**	**−1.2%**	**−1.3%**	**1.4%**
		TOTAL INORGANICS IN TOP 50	**315.94**	**373.45**			**−15.4%**	**−2.7%**	**−1.3%**	**0.5%**
		GRAND TOTAL OF TOP 50	**466.22**	**547.39**			**−14.8%**	**−2.2%**	**−1.3%**	**0.8%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons. c Except refractory dolomite. d Synthetic and natural. e Original solution. f 100% basis. g. All grades. h All forms. i Includes both acid and ester without double counting. j 37% by weight. k Synthetic only. l Rubber grade. m High and low purity. n Solid and liquid.
Sources: Bureau of the Census, Bureau of Mines, International Trade Commission, C&EN estimates

PRODUCTION: Dropped last year in all sections of chemical industry

Industrial production indexes, 1967 = 100												Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
Total index	138.6	151.0	147.0	152.5	146.1	138.2	130.5	117.8	129.3	129.8	119.7	−8%	1%
Manufacturing, total	137.6	150.4	146.7	153.6	146.8	138.4	130.3	116.3	129.4	129.8	118.9	−9	1
Nondurable manufacturing	156.2	164.8	161.2	164.0	156.9	150.5	141.8	126.4	134.6	133.8	126.5	−5	2
Chemicals and products	196.1	215.6	207.1	211.8	197.4	185.7	170.9	147.2	159.4	154.5	143.6	−9	3
Chemicals and synthetic materials	196.7	228.6	222.2	234.2	216.7	201.1	185.1	154.1	176.7	171.9	156.4	−14	2
Basic chemicals	157.1	186.8	187.4	192.0	181.9	171.8	161.8	135.9	153.3	147.7	137.7	−16	1
Alkalies and chlorine	99.2	114.7	121.4	132.3	119.7	119.2	119.0	106.5	125.6	123.8	120.2	−14	−2
Gases, coal tar, inorganic pigments	160.0	181.5	184.3	197.7	186.0	174.3	164.4	133.3	165.0	157.8	146.5	−12	1
Basic organic chemicals	192.9	236.7	231.6	233.3	221.2	204.7	189.8	155.3	177.9	170.0	155.3	−19	2
Inorganic chemicals, nec	109.9	125.5	132.4	134.9	129.3	128.5	124.3	112.9	112.6	110.8	107.8	−12	0
Acids and fertilizer materials	116.0	137.2	145.9	142.0	133.6	124.2	117.6	108.4	116.6	113.1	111.5	−15	0
Synthetic materials	277.4	313.7	293.3	320.1	287.6	260.8	232.5	191.0	224.4	221.1	194.7	−12	4
Plastics materials	403.6	429.3	386.5	420.1	366.5	320.3	280.1	213.1	258.5	243.3	217.4	−6	6
Synthetic rubber	84.9	103.3	103.2	130.5	127.5	124.5	118.7	101.2	129.7	135.6	126.9	−18	−4
Man-made fibers	204.2	254.4	250.3	270.8	250.9	236.8	214.3	191.2	214.4	220.1	189.1	−20	1
Chemical products	195.8	203.0	192.4	190.2	179.0	170.9	157.2	140.7	142.8	137.7	131.3	−4	4
Drugs and medicines	266.8	267.1	245.7	238.2	220.6	213.9	191.5	174.1	179.6	170.1	155.5	0	6
Soap and toiletries	171.5	177.0	170.8	171.6	163.8	155.0	143.0	127.7	128.1	129.0	130.3	−3	3
Paints	115.3	127.4	130.5	137.8	132.6	125.8	122.8	114.2	119.2	114.7	118.0	−9	0
Agricultural chemicals	208.7	241.4	230.5	221.6	211.8	201.1	185.4	163.9	144.6	127.0	108.9	−14	7
Petroleum products	121.8	129.7	132.9	143.9	145.2	142.6	133.5	124.1	124.7	128.5	122.1	−6	0
Rubber and plastics products	254.7	274.0	255.7	272.2	253.6	232.3	199.7	166.7	195.2	184.1	172.4	−7	4

nec = not elsewhere classified. **Source:** Federal Reserve Board

MINERALS: Fertilizer raw material production fell again in 1982

Thousands of tons												Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
Bromine, sold or used[a]	200[b]	189	189	249	223	217	230	204	216	209	193	6%	0%
Calcium chloride, production[c,d]	875	917	811	981	1,031	968	897	823	1,101	858	914[e]	−5	0
Iodine, consumption[f,g]	4.0[b]	4.4	4.4	4.4	4.0	4.3	3.6	3.1	3.8	3.5	3.4	−10	2
Imports[g]	2.8[b]	3.0	3.1	3.1	3.4	3.5	3.2	2.7	4.0	3.1	3.1	−7	−1
Lime, sold or used[h]	14,202[b]	18,890	19.037	20,983	20,484	19,987	20,257	19,159	21,645	21,132	20,332	−25	−4
Lithium, consumption[f,i]	2.9[b]	3.2	3.0	3.2	3.4	4.1	2.8	2.9	3.8	3.2	2.7	−10	1
Phosphate rock													
Marketable production	41,241	59,110	59,982	56,891	55,156	52.091	49,231	48,806	45,676	42,128	40,823	−30	0
Exports	10.849	11,458	15,737	15,827	14,187	14.584	10,398	12,270	13,895	13,873	14,272	−5	−3
Potash (K_2O equivalent)[j]													
Production	1,929[b]	2,377	2,468	2,453	2,484	2,457	2,400	2,501	2,552	2,604	2,659	−17	−3
Imports[k]	5,291[b]	5,287	5,481	5,693	5,189	5,076	4,594	3,797	4,325	3,587	2,961	0	6
Apparent consumption	6,614[b]	6,849	6,999	7,626	6,840	6,605	6,149	5,113	6,086	5,583	4,813	−3	3
Salt, total sold or used[l]	38,700[b]	38,915	40,396	45,820	42,896	43,439	44,218	41,057	46,565	43,939	45,051	−1	−2
Evaporated	5,418[b]	6,209	6,358	6,248	5,872	5,704	5,634	5,372	5,951	5,913	5,879	−13	−1
Rock	13,158[b]	11,871	11,806	14,891	14,688	14,958	15,668	14,283	14,835	12,347	14,434	11	−1
Salt in brine[m]	20,124[b]	20,835	22,231	24.681	22.336	22,777	22,917	21,401	25,779	25,680	24,737	−3	−2
Sodium carbonate, production[d]	8,000[b]	8,281	8,275	8,253	8,290	8,040	7,560	7,130	7,566	7,535	7,523	−3	1
Sulfur, production[n]	10,788	13,388	13,080	13,339	12,318	[illegible],824	11,992	12,610	12,789	12,231	11,444	−19	−1
Apparent consumption[o]	11,088	14,093	15,056	15,145	13,889	12,850	12,060	11,875	12,115	11,463	11,036	−21	0
Frasch, production	4,641	6,997	7,044	7,007	6,226	6,520	7,016	8,077	8,849	8,518	8,165	−34	−6
Recovered elemental, production	4,855	4,695	4,490	4,486	4,478	3,995	3,514	3,326	2,948	2,706	2,184	3	8
Other, production	1,293	1,695	1,547	1,845	1,615	1,310	1,462	1,208	992	1,008	1,096	−24	2

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. b Preliminary figure. c 75% $CaCl_2$ equivalent. d Natural and synthetic. e C&EN estimate. f Estimated apparent consumption. g Crude elemental iodine. h Includes Puerto Rican production. i Lithium content basis. j Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. k Includes nitrate of potash. l Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures except for 1982 include Puerto Rican production. m Sold or used as such. n Sulfur content basis. o Calculated from shipments plus imports minus exports (sulfur content basis). **Source:** Bureau of Mines

ORGANIC CHEMICALS: Steep declines marked output of most products in 1982

Millions of lb unless otherwise noted	Production											Annual change	
	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981-82	1972-82
Acetic acid, synthetic	2,751	2,705	2,977	3,265	2,776	2,570	2,463	2,197	2,584	2,429	2,235	2%	2%
Acetone	1,757	2,144	2,076	2,653	2,519	2,219	1,869	1,640	1,980	1,989	1,8[illegible]8	−18	0
Acrylonitrile	2,041	1,997	1,830	2,018	1,752	1,646	1,518	1,215	1,412	1,354	1,115	2	6
Aniline	557	634	659	690	606	584	544	407	551	458	410	−12	3
Benzene, mg[b,c]	1,073	1,339	1,585	1,673	1,488	1,457	1,425	1,024	1,488	1,453	1,252	−20	−2
Bisphenol A	479	555	530	576	471	455	449	293	370	320	255	−14	6
1,3-Butadiene[d]	1,826	2,986	2,799	3,583	3,515	3,259	3,507	2,597	3,682	3,644	3,527	−39	−6
Butanol	706	809	790	766	756	660	625	490	558	519	590	−13	2
Caprolactam	797	928	905[e]	945	919	867	780	713	668	656	640	−14	2
Carbon disulfide	na	388	377	448	476	505	508	479	782	777	768	na	na
Carbon tetrachloride	588	726	710	714	737	809	857	906	1,163	1,047	997	−19	−5
Cumene	2,678	3,309	3,459	3,917	3,380	2,644	2,716	2,003	2,906	2,665	2,293	−19	2
Cyclohexane	1,272	1,820	1,964	2,425	2,332	2,265	2,187	1,734	2,352	2,123	2,298	−30	−6
Diisodecyl phthalate	108	140	122	175	171	161	143	106	147	171	153	−23	−3
Dodecylbenzene[f]	484	535	563[e]	627	526	526	529	495	533	498	524	−10	−1
Ethanol, synthetic	1,028	1,317	1,451	1,408	1,267	1,339	1,496	1,429	1,618	1,962	1,851	−22	−6
Ethanolamines[g]	403	429	376	420	362	308	286	258	307	293	284	−6	4
Ethyl chloride	339	324	396	582	540	612	669	575	662	660	576	5	−5
Ethylbenzene	6,674	7,813	7,642	8,448	8,385	8,312	5,770	4,822	6,048	5,688	5,676	−15	2
Ethylene	24,683	29,418	28,667	29,904	25,955	25,172	22,475	20,499	23,891	22,329	20,852	−16	2
Ethylene dichloride	9,985	9,974	11,108	11,794	11,001	10,997	8,042	7,977	9,165[h]	9,293[h]	7,809	0	2
Ethylene glycol	4,295	4,143	4,386	4,729	3,904	3,675	3,335	3,809	3,341	3,278	3,761	4	1
Ethylene oxide	5,000	4,937	5,220	5,665	5,012	4,364	4,184	4,467	4,200[i]	4,167	3,962	0	2
2-Ethylhexanol	321	389	367	318	420	493	450	387	395	402	526	−17	−5
Formaldehyde, 37%[j]	4,691	5,721	5,555	5,971	6,381	6,046	5,449	4,558	5,764	6,424	5,652	−20	−2
Isopropyl alcohol	1,310	1,669	1,836	1,900	1,730	1,888	1,936	1,521	1,939	1,835	1,790	−22	−3
Maleic anhydride	259	293	304	323	341	294	264	216	290	282	274	−12	−1
Methanol, synthetic	7,265	8,577	7,153	7,367	6,443	6,453	6,242	5,176	6,878	7,064	6,472	−15	1
Methyl chloride	370	405	362	463	454	476	378	366	493[h]	544[h]	454	−9	−2
Methyl ethyl ketone	462	611	587	656	661	512	428	425	506	541	509	−24	−1
Methyl chloroform	586	614	692	716	644	635	631	459	592	548	441	−5	3
Methylene chloride	524	592	564	633	570	478	538	497	609	520	471	−11	1
Perchloroethylene	585	691	765	773	725	614	669	679	734	706	734	−15	−2
Phenol, synthetic[k]	2,136	2,578	2,568	2,981	2,682	2,338	2,121	1,746	2,298	2,241	2,052	−17	0
Phthalic anhydride	691	870	818	1,013	978	926	902	702	977	1,023	933	−21	−3
Propylene[c]	12,290	13,482	13,676[l]	14,198[l]	13,014[l]	13,328[l]	10,030[l]	8,709[l]	10,475[m]	9,884[m]	8,472[m]	−9	4
Propylene glycol	403	473	488	610	547	489	517	391	510	502	563	−15	−3
Propylene oxide	na	na	1,767	2,249	2,047	1,866	1,823	1,524	1,756	1,753	1,520	na	na
Styrene, monomer	5,928	6,679	6,856	7,484	7,186	6,867	6,301	4,673	5,956	5,975	5,941	−11	0
Terephthalic acid, dimethyl ester[n]	4,974	6,235	6,054	6,159	5,954	5,410	5,051	4,614	4,262	2,564[o]	4,405[p]	−39	1
Toluene, mg[b,c]	1,057	856	1,017	1,010	1,054	1,018	999	705	922	958	916	23	1
Vinyl acetate	1,876	1,936	1,922	1,982	1,692	1,586	1,481	1,290	1,403	1,503	1,211	−3	4
Vinyl chloride	6,495	6,874	6,466	6,389	6,941	5,986	5,677	4,196	5,621	5,351	5,089	−6	2
***o*-Xylene**	799	918	995	1,082	1,013	985	854	703	1,056	1,068	832	−13	0
***p*-Xylene**	2,926	4,532	4,238	4,650	3,516	3,172	2,911	2,484	2,707	2,326	2,208	−35	3

a Preliminary. **b** Tar distillers not included; includes material for use in blending motor fuels. **c** All grades. **d** Rubber grade. **e** Preliminary figure; final figure not available. **f** Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. **g** Mono-, di-, and triethanolamines. **h** Production figure may be too low, because some methyl chloride and ethylene dichloride were produced but not separated or measured accurately by some producers. **i** Approximate. **j** By weight. **k** Does not include data for coke ovens and gas retort ovens. **l** Includes refinery propylene. **m** Includes data for propane-propylene mixture. **n** Includes both acid and and dimethyl ester (DMT), without double counting. **o** Includes only dimethyl ester. **p** Figure may be too high because of possible double counting of some acid and ester. **mg** = millions of gallons. **na** = not available. **Source:** International Trade Commission

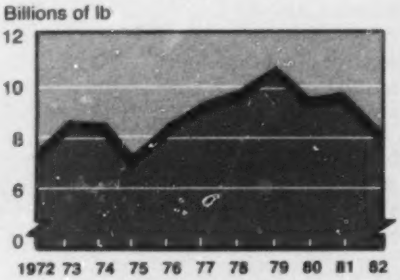
INORGANICS: Production in 1982 frequently little changed from a decade ago

Thousands of tons unless otherwise noted	Production											Annual Change	
	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
Aluminum sulfate[b]	1,186	1,294	1,286	1,315	1,309	1,255	1,202	1,146	1,257	1,233	1,193	−8%	0%
Ammonia,[c,d] 100%	15,488	19,076	19,653	18,634	17,119	17,765	16,716	16,419	15,733	15,208	15,169	−19	0
Ammonium nitrate,[e] 100%	7,331	8,936	9,128	8,293	7,210	7,177	7,186	7,088	7,542	7,235	6,863	−18	1
Ammonium sulfate,[d,f] 100%	1,785	2,194	2,136	2,363	2,449	2,264	2,010	2,106	2,120	1,987	1,858	−19	0
Chlorine gas[g]	9,120	10,767	11,421	12,291	11,052	10,573	10,378	9,167	10,753	10,402	9,854	−15	−1
Hydrochloric acid,[h] 100%	2,483	2,502	2,888	3,090	2,793	2,668	2,542	2,009	2,470	2,534	2,360	−1	1
Hydrogen,[i,j] bcf, 100%	91	103	107	106	90	85	82	74	82	65	59	−12	4
Nitric acid, 100%	7,608	9,077	9,231[k]	8,916[k]	7,934[k]	7,987[k]	7,791[k]	7,527[k]	8,120[k]	8,398[k]	7,981[k]	−16	0
Nitrogen gas,[i,j] bcf, 100%	484	490	479	427	379	328	289	252	243	227	194	−1	10
Oxygen,[i,j] bcf, 100%	358	431	431	456	430	392	388	353	390	38[illegible]	352	−17	0
Phosphoric acid, 100% P_2O_5	8,523	9,922	10,848	10,318	9,637	8,745	7,949	7,677	7,213	6,927	6,712	−14	2
Phosphorus[m]	361	426	432	460	441	430	437	450	524	526	541	−15	−4
Sodium chlorate, 100%	247	302	312	269	265	251	199	173	203	204	194	−18	2
Sodium hydroxide, 100%	9,141	10,414	11,625	12,759	11,309	11,000	10,516	9,635	11,189	10,734	10,216	−12	−1
Sodium phosphate[n]	632	696	727	757	739	717	724	770	903	967	1,033	−9	−5
Sodium silicate[o]	649	788	805	8[illegible]3	829	760	747	724	770	723	661	−18	0
Sodium sulfate,[p] 100%	902	1,077	1,140	1,121	1,174	1,199	1,232	1,227	1,348	1,437	1,327	−16	−4
Sulfuric acid,[q] 100%	32,304	40,795	44,158	43,204	41,314	38,337	34,878	32,360	33,936	31,949	31,183	−21	−0
Titanium dioxide,[r] 100%	635	761	727	742	701	687	713	603	787	785	693	−17	−1
Urea, 100%	5,931	8,103	7,830	7,000	6,273	5,072	4,498	3,799	3,788	3,543	3,467	−27	6

a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities except in 1981. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts of nitric acid produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Tripolyphosphate (100% $Na_5P_3O_{10}$). o Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. p Anhydrous, high and low purity, and Glauber's salt. q Gross (new and fortified). r Composite and pure. **Note:** bcf = billions of cubic feet. **Sources:** Department of Commerce, International Trade Commission

MAN-MADE FIBERS: U.S. output in 1982 was the lowest since the mid-1970s

Man-made fibers production

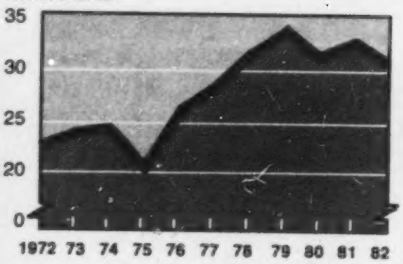


Millions of lb	Production											Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
CELLULOSIC FIBERS													
Acetate[a]	196	261	316	324	308	290	298	313	382	462	429	−25%	−8%
Rayon	388	509	490	606	597	598	543	436	817	895	965	−24	−9
NONCELLULOSIC FIBERS													
Acrylic[b]	624	691	779	761	726	709	621	525	631	742	626	−10	0
Nylon[c]	1927	2332	2358	2,720	2550	2326	2075	1857	2124	2175	1974	−17	0
Olefins[d]	723	785	748	759	692	635	577	497	531	492	416	−8	6
Polyester	3169	4176	3989	4,178	3800	3642	3340	2995	2926	2888	2328	−24	3
Textile glass	899	1041	867	1,014	923	787	676	546	683	688	572	−14	5
Other[e]	17	22	19	18	16	16	14	12	12	13	11	−23	4
TOTAL	**7943**	**9817**	**9566**	**10,381**	**9611**	**9002**	**8144**	**7181**	**8105**	**8354**	**7322**	**−20%**	**1%**

a Includes diacetate and triacetate; excludes production for cigarette filtration. b Includes modacrylic. c Includes aramid. d Includes olefin yarn and monofilaments, and olefin and vinyon staple and tow. e Includes only yarn and monofilaments; yarn is chiefly saran and spandex. **Source:** Textile Economics Bureau

Plastics production

Billions of lb



PLASTICS: Output in 1982 dropped back to 1980's depressed level

Millions of lb[a]	Production											Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
THERMOSETTING RESINS													
Epoxy[b]	286	336	315	361	299	261	244	198	249	223	184	−15%	4%
Polyester[c]	865	997	947	1,147	1,209	1,061	1,042	834	911	1,051	933	−13	−1
Urea	998	1,165	1,165	1,367	1,122	963	821	690	835	867	739	−14	3
Melamine	158	179	167	200	202	200	186	115	164	170	171	−12	−1
Phenolic[d]	2,006[e]	2,333[e]	1,499	1,781	1,617	1,458	1,340	1,051	1,335	1,387	1,453	−14	na
TOTAL	**4,313**	**5,010**	**4,094**	**4,857**	**4,448**	**3,943**	**3,631**	**2,888**	**3,494**	**3,698**	**3,481**	−14	na
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	7,503	7,693	7,291	7,793	7,111	6,471	5,813	4,743	5,973	5,803	5,274	−2	4
High density[g]	4,928	4,695	4,405	5,010	4,201	3,652	3,125	2,468	2,837	2,637	2,325	5	8
Polypropylene	3,477	3,955	3,648	3,841	3,074	2,747	2,632	1,902	2,249	2,162	1,726	−12	7
Acrylonitrile-butadiene-styrene	740	916	920	1,191	1,134	1,069	988	642	857	877	810	−19	−1
Styrene-acrylonitrile	91	107	111	124	120	115	113	109	109	121	99	−15	−1
Polystyrene	3,191	3,621	3,521	4,005	3,823	3,446	3,195	2,662	3,364	3,322	3,139	−12	0
Styrene-butadiene copolymers and other styrene resins	640	829	785	916	878	813	756	585	679	703	624	−23	0
Polyamide, nylon type	228	312	274	327	275	254	247	135	204	205	157	−27	4
Polyvinyl chloride and copolymers	5,326	5,707	5,470	6,119	5,723	5,253	4,716	3,648	4,850	4,562	4,259	−7	2
Other vinyl resins[h]	177	208	196	220	197	197	225	187	209	199	194	−15	−1
TOTAL	**26,301**	**28,043**	**26,621**	**29,546**	**26,536**	**24,017**	**21,870**	**17,081**	**21,331**	**20,591**	**18,607**	**−6%**	**40%**

a Dry-weight basis, unless otherwise specified. b Unmodified. c Unsaturated. d Includes other tar acid resins. e Gross weight basis. f 0.940 density and below. g Density above 0.940. h Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene chloride. **na = not available. Source:** Society of the Plastics Industry

SYNTHETIC RUBBER: Output plunged last year from already low levels

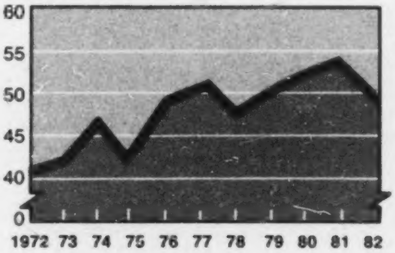
Thousands of metric tons	Production											Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981–82	1972–82
Styrene-butadiene rubber[a]	876	1032	1074	1378	1395	1395	1333	1179	1466	1537	1500	−15%	−5%
Polybutadiene	288	342	311	397	378	361	352	290	310	337	299	−16	0
Nitrile	45	66	63	75	73	70	73	55	88	84	75	−32	−5
Ethylene-propylene	123	178	144	175	174	158	130	84	126	120	91	−31	3
Polychloroprene	119	143	151	183	161	165	165	144	163	na	na	−17	na
Butyl				194	154	149	125	80	164	160	131	−31	−5[b]
Polyisoprene						62	74	61	93	119	134		
Other[c]	181[d]	261[d]	272[d]	132[d]	138[d]	56	51	47	88	270[e]	226[e]		
TOTAL	**1632**	**2022**	**2015**	**2534**	**2475**	**2418**	**2304**	**1941**	**2498**	**2627**	**2456**	**−19%**	**−4%**

a Excludes high-styrene latex (more than 45% styrene). b Annual change for 1972–82 calculated by comparing polychloroprene plus other (including butyl and polyisoprene) in 1982 with butyl, polyisoprene, and other (including polychloroprene) in 1972. c Excludes polyurethane rubber. d Includes butyl rubber in 1980–82 and polyisoprene in 1978–82. e Includes polychloroprene (neoprene). na = not available. **Source:** Rubber Manufacturers Association, Department of Commerce

FERTILIZERS: U.S. production and exports both slumped sharply last year

Fertilizer consumption

Millions of tons



Note: Years ending June 30.
Source: Department of Agriculture

Thousands of tons	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981-82	Annual change 1972-82
Nitrogen (N)													
Domestic production	11,598	13,036	12,323	11,106	10,466	10,789	10,572	9343	10,094	9447	8971	−11%	3%
Imports	2,531	2,455	2,566	2,165	1,866	1,842	1,218	1198	1,068	882	843	3	12
Exports	2,499	3,088	2,641	2,468	1,778	1,251	1,239	1115	1,269	1508	1032	−19	9
Domestic supply	11,630	12,403	12,248	10,803	10,554	11,380	10,551	9426	9,893	8821	8782	−6	3
PHOSPHATE (P_2O_5)													
Domestic production	7,818	10,471	10,012	9,432	8,245	7,793	7,199	7230	6,869	6387	6150	−25	2
Imports	193	250	239	236	229	245	221	274	315	312	326	−23	−5
Exports	3,751	4,381	3,925	3,848	3,290	2,501	2,175	1860	1,581	1422	1102	−14	13
Domestic supply	4,260	6,340	6,326	5,820	5,184	5,537	5,245	5644	5,603	5277	5374	−33	−2
POTASH (K_2O)													
Domestic production	1,831	2,262	2,474	2,519	2,176	2,584	2,313	2287	2,604	2690	2432	−19	−3
Imports	4,797	5,487	5,403	5,085	4,948	4,955	3,910	3847	4,114	3192	3088	−13	5
Exports	641	876	1,048	999	1,003	994	911	848	947	922	657	−27	0
Domestic supply	5,987	6,873	6,829	6,605	6,121	6,545	5,312	5286	5,771	4960	4863	−13	2

Total fertilizer consumption in the U.S. down 10%

	Consumption											Annual change	
Thousands of tons	**1982**	**1981**	**1980**	**1979**	**1978**	**1977**	**1976**	**1975**	**1974**	**1973**	**1972**	**1981-82**	**1972-82**
TYPE													
Mixed fertilizer	20,815	23,525	23,270	23,742	22,110	24,099	22,958	20,647	24,067	22,547	21,511	−12%	0%
Primary nutrient material[a]	27,918	30,463	27,221	25,600	23,511	24,999	23,935	19,959	20,897	19,275	18,385	−8	4
Secondary and micronutrients[b]	—	—	2,296	2,139	1,877	2,525	2,296	1,878	2,130	1,466	1,310	—	
TOTAL	**48,733**	**53,988**	**52,787**	**51,481**	**47,497**	**51,624**	**49,189**	**42,484**	**47,094**	**43,258**	**41,206**	**−10%**	**2%**
PRIMARY NUTRIENT CONTENT													
Nitrogen (N)	11,079	11,924	11,407	10,715	9,965	10,647	10,412	8,601	9,157	8,295	8,022	−7	3
Phosphate (P_2O_5)	4,818	5,434	5,432	5,606	5,096	5,630	5,228	4,507	5,099	5,085	4,864	−11	0
Potash (K_2O)	5,614	6,320	6,245	6,244	5,526	5,834	5,210	4,453	5,083	4,649	4,327	−11	3
TOTAL	**21,511**	**23,678**	**23,083**	**22,565**	**20,587**	**22,111**	**20,849**	**17,561**	**19,338**	**18,029**	**17,213**	**−9%**	**2%**

a Includes secondary and micronutrients in 1981 and 1982. b Included in primary nutrient material in 1981 and 1982. **Note:** Years ending June 30. **Source:** Department of Agriculture

NITROGEN OUTPUT: Ammonia slips 8%

Thousands of tons (N)	1982	1981	1980	1972	Change 1981-82
Ammonia[a]	5,032	5,455	5,270	3838	−8%
Ammonium nitrate[b,c]	1,105	1,225	1,096	1246	−10
Urea	1,684	1,704	1,572	585	−1
Ammonium sulfate[c]	432	555	521	497	−22
All other	3,345	4,097	3,864	2788	−18
TOTAL	**11,598**	**13,036**	**12,323**	**8954**	**−11%**

a Includes aqueous solutions. b Includes ammonium nitrate-limestone mixtures. c Adjusted for estimated quantity going into nonfertilizer uses. **Note:** Years ending June 30. **Source:** Department of Agriculture

PHOSPHATE OUTPUT: Dropped 25% in 1982

Thousands of tons (P_2O_5)	1982	1981	1980	1972	Change 1981-82
Ammonium phosphate[a]	4434	6,015	5,519	2430	−26%
Concentrated superphosphate	1151	1,713	1,737	1667	−33
Normal and enriched superphosphate	153	357	384	678	−57
All other	2080	2,386	2,372	1399	−13
TOTAL	**7818**	**10,471**	**10,012**	**6174**	**−25%**

a Liquid and solid, excluding that combined with potash salts in process of manufacture.

Finances of the U.S. Chemical Industry 2

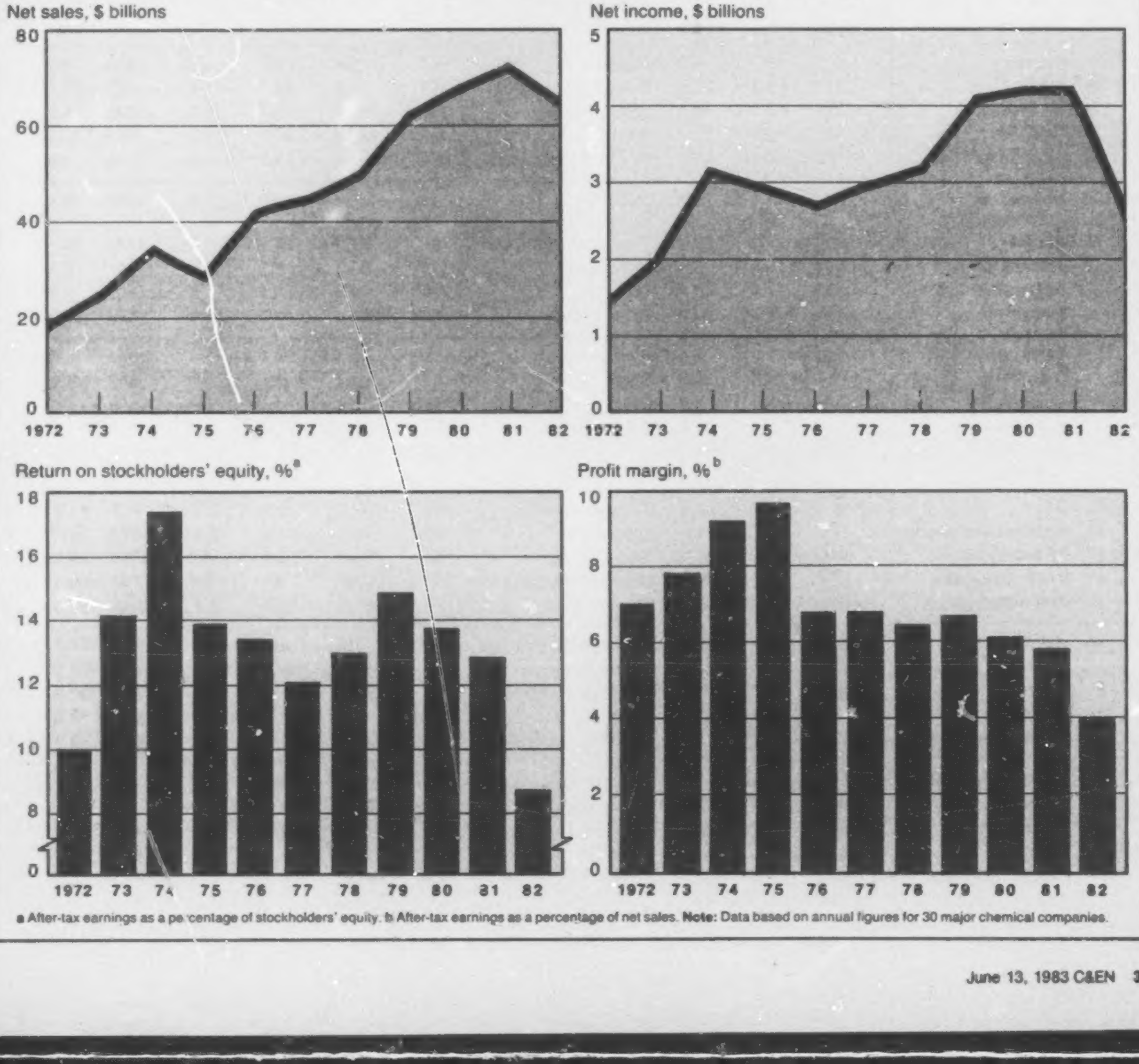
Profits staggered by lower demand, prices

For the chemical industry, as for nearly all other segments of U.S. business, 1982 was a financial wasteland. In contrast to the preceding 1980 recession, when a drop in physical demand was more than offset by higher selling prices, both demand and prices were weak last year. As a result, sales volume fell. For example, the dollar value of shipments of both industrial chemicals alone and chemicals and allied products as a whole declined for the first time since 1958, when the Department of Commerce began keeping its current series of statistics on manufacturers' shipments.

And despite Herculean efforts to cut operating expenses and the easing of some materials and energy costs, the industry's profits nosedived (again in contrast to 1980) in the wake of depressed revenues, rock-bottom levels of capacity utilization, and higher unit labor costs. Net income for the major chemical producers was off about a third from the year before, dropping to the lowest level since 1976.

Profitability, which had been slipping since 1979, also plummeted, down to what is probably the lowest level since World War II. Last year, chemical companies were earning less than half of what they were earning on each dollar of sales seven or eight years ago.

Sales of chemical producers fell last year for the first time since 1975 and earnings skidded to the lowest level since 1973, severely undercutting profitability



a After-tax earnings as a percentage of stockholders' equity. b After-tax earnings as a percentage of net sales. **Note:** Data based on annual figures for 30 major chemical companies.

TOP 100 CHEMICAL PRODUCERS: In 1982, few eked out an increase in their chemical sales . . .

Rank 1982	Rank 1981[a]	Company	Chemical sales 1982 ($ million)	Change from 1981	Chemical sales as % of total sales	Industry classification	Chemical operating profit[b]	Change from 1981	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets	Chemical assets % of total assets	Operating return on chemical assets[d]
1	1	**Du Pont**	$10,841	−5.8%	32.5%	Diversified	$417	−63.7%	10.6%	3.8%	$7745	36.6%	5.4%
2	2	**Dow Chemical**	8,252	−12.1	77.7	Basic chemicals	226	−63.1	63.5	2.7	8124	66.8	2.8
3	3	**Exxon**	7,259	−14.0	7.1	Petroleum	47	−86.5	0.6	0.6	5047	8.1	0.9
4	4	**Monsanto**	5,737[e]	−9.1	90.7	Basic chemicals	497	−26.0	99.2	8.7	5234	86.1	9.5
5	5	**Union Carbide**	4,985	−13.7	55.0	Basic chemicals	294	−49.3	44.7	5.9	6027	57.3	4.9
6	7	**Shell Oil**	3,085	−14.4	15.4	Petroleum	−56	def	def	def	3841	18.0	def
7	6	**Celanese**	3,062	−18.4	100.0	Basic chemicals	39	−82.3	100.0	1.3	2862	100.0	1.4
8	8	**Standard Oil (Ind.)**	2,786	−9.8	9.4	Petroleum	133	−36.7	3.7	4.8	2530	10.6	5.3
9	10	**W. R. Grace**	2,654	−4.0	43.2	Specialty chemicals	303	−23.5	50.2	11.4	1608	34.5	18.8
10	11	**Allied**	2,407	−13.7	39.0	Diversified	105	−50.2	13.4	4.4	1726	27.5	6.1
11	12	**Phillips Petroleum**	2,356	−4.6	15.0	Petroleum	23	−83.6	1.0	1.0	1563	14.9	1.5
12	9	**Atlantic Richfield**	2,242	−18.1	8.3	Petroleum	−96	def	def	def	2608	12.1	def
13	14	**Eastman Kodak**	2,151	−8.4	19.9	Photo equipment	205	−29.1	11.0	9.5	2001	19.3	10.2
14	15	**Mobil**	2,148	−7.6	3.3	Petroleum	6	−95.1	0.1	0.3	2075	5.8	0.3
15	16	**Hercules**	2,040	−10.3	82.6	Basic chemicals	75	−55.9	65.8	3.7	1468	90.4	5.1
16	13	**Gulf Oil**	2,006	−18.3	6.6	Petroleum	−329	def	def	def	1232	6.6	def
17	18	**Rohm & Haas**	1,727	−1.9	94.5	Basic chemicals	156	−16.6	98.7	9.0	1008	90.7	15.5
18	17	**American Cyanamid**	1,698[e]	−12.7	49.2	Basic chemicals	100	−49.5	43.4	5.9	1308	56.5	7.6
19	19	**Stauffer Chemical**	1,618	−6.3	100.0	Basic chemicals	285	−7.3	100.0	17.6	1756	100.0	16.2
20	20	**American Hoechst**	1,506[e]	−6.4	100.0	Basic chemicals	na	na	na	na	na	na	na
21	22	**Texaco**	1,497	−16.7	3.2	Petroleum	−20	def	def	def	953	4.5	def
22	23	**Ethyl**	1,411[e]	−6.9	87.4	Basic chemicals	161	4.5	84.5	11.4	959	86.7	16.8
23	28	**Air Products**[f]	1,359	−0.2	86.6	Basic chemicals	189	−4.2	93.7	13.9	1596	73.6	11.8
24	27	**FMC**	1,319	−4.6	37.7	Machinery	149	−23.4	81.7	11.3	1084	39.2	13.7
25	31	**Ciba-Geigy**	1,285	−0.9	68.0	Specialty chemicals	na	na	na	na	na	na	na
26	26	**Occidental Petroleum**	1,260[g]	−11.5	6.7	Petroleum	15	−86.4	0.8	1.2	1209	8.8	7.1
27	25	**Borden**	1,220[e]	−14.4	29.7	Dairy products	86	−37.7	29.5	7.0	1271	49.1	6.8
28	30	**Ashland Oil**	1,197	−10.0	13.1	Petroleum	28	−31.7	8.3	2.3	402	9.5	7.0
29	33	**Union Oil of Calif.**	1,153	−7.6	10.6	Petroleum	90[h]	−19.3	11.1	7.8	671	7.9	13.4
30	32	**Mobay**	1,132	−9.4	100.0	Basic chemicals	3[h]	−94.6	100.0	0.3	1213	100.0	0.3
31	21	**Tenneco**	1,108	−7.5	7.4	Petroleum	15	−53.1	0.8	1.4	963	6.2	1.6
32	24	**U.S. Steel**	1,077	−24.6	5.7	Steel	−31	def	def	def	592	3.0	def
33	34	**Standard Oil of Calif.**	1,047	−14.1	3.0	Petroleum	−16[h]	def	def	def	825	4.0	def
34	38	**B. F. Goodrich**	1,015	−3.1	33.8	Rubber products	1	−96.3	def	0.1	1186	50.0	0.1
35	29	**International Minerals**[i]	1,013	−17.4	64.9	Agri. chemicals	169	−43.0	79.1	16.7	1345	69.3	12.6
36	36	**Olin**	1,012	−6.0	55.5	Basic chemicals	22	−53.7	16.6	2.2	914	61.7	2.4
37	35	**Diamond Shamrock**	996	−12.7	31.3	Petroleum	83	−44.9	34.2	8.3	1024	32.1	8.1
38	37	**CF Industries**	919[e]	−12.8	100.0	Agri. chemicals	−38	def	def	def	1008	100.0	def
39	41	**BASF Wyandotte**	895	−7.5	100.0	Basic chemicals	−3	def	def	def	735	100.0	def
40	39	**PPG Industries**	893	−11.8	30.1	Glass products	39	−67.5	16.4	4.4	1045	32.0	3.7
41	40	**Williams Cos.**	828[e]	−15.9	49.0	Agri. chemicals	−30	def	def	def	981	51.7	def
42	42	**Reichhold Chemicals**	815	−14.2	100.0	Basic chemicals	17	−52.8	100.0	2.1	356	100.0	4.8
43	43	**Lubrizol**	812	−9.7	100.0	Specialty chemicals	103	−34.4	100.0	12.7	569	100.0	18.1
44	44	**Eli Lilly**	789	−5.8	26.6	Drugs	147	−12.0	20.8	18.6	638	26.6	17.5
45	45	**National Distillers**	758	−10.9	41.4	Alcoholic beverages	58	−49.1	50.9	7.7	614	35.9	9.4
46	46	**Farmland Industries**[i]	664	−18.6	11.8	Agri. supplies	−8	def	def	def	486	29.3	def
47	49	**Dow Corning**	663	−8.2	100.0	Specialty chemicals	53[h]	−30	100.0	8.0	na	na	na
48	51	**Nalco Chemical**	644	−3.4	100.0	Specialty chemicals	99	−18.9	100.0	15.4	465	100.0	21.3
49	53	**Merck**	644	−3.0	21.0	Drugs	60	−18.1	9.9	9.3	566	18.6	10.6
50	63	**Kaiser Aluminum**	642	−0.3	22.1	Nonferrous metals	44	−53.0	80.0	6.9	519	14.2	8.5

a Revised. b Sales less administrative expense and cost of selling. c Operating profit as a percentage of chemical sales. d Operating profit as a percentage of identifiable chemical assets. e Chemical sales include significant amounts of nonchemical products. f Fiscal year ended Sept. 30, 1982. g Does not include all chemical products. h Chemical net profit. i Fiscal year

. . . and all who did so ranked in size among the lower 50

Rank 1982	Rank 1981[a]	Company	Chemical sales 1982 ($ millions)	Change from 1981	Chemical sales as % of total sales	Industry classification	Chemical operating profits[b]	Change from 1981	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets	Chemical assets % of total assets	Operating return on chemical assets[d]
51	59	**Esmark**[k]	$630[e]	−3.0%	18.6%	Food	$ 23	−37.9%	12.6%	3.7%	$370	21.0%	6.2%
52	47	**Georgia-Pacific**	628	−14.9	11.6	Wood products	75	−49.7	31.9	11.9	1025	24.7	7.3
53	52	**Borg-Warner**	613	−7.7	19.2	Auto equipment	52	−15.4	22.8	8.5	297	17.7	17.5
54	54	**Pennwalt**	581	−9.4	61.0	Basic chemicals	46	−36.9	61.7	7.9	438	68.2	10.5
55	68	**Standard Oil (Ohio)**	554	12.8	4.1	Petroleum	−23	def	def	def	534	3.3	def
56	50	**Koppers**	535[e]	−21.1	33.8	Diversified	16	−64.1	25.4	2.9	327	29.7	4.7
57	47	**Sun Co.**	516	−30.8	3.1	Petroleum	na	na	na	na	na	na	na
58	56	**Uniroyal**	516	−10.0	26.2	Rubber products	42	−46.8	38.1	8.1	425	36.6	9.9
59	64	**Witco Chemical**	513	0.5	39.3	Specialty chemicals	39	−19.2	34.0	7.5	241	36.4	16.0
60	58	**Badische**	501	−11.0	100.0	Basic chemicals	−8	def	def	def	483	100.0	def
61	61	**Aluminum Co. of America**	493[e]	−5.7	10.7	Nonferrous metals	na	na	na	na	na	na	na
62	62	**Kerr-McGee**	488	−10.0	12.9	Petroleum	−10	def	def	def	656	18.1	def
63	57	**NL Industries**	477	−15.6	21.5	Petroleum services	61	−21.4	21.4	12.8	307	13.4	19.9
64	65	**Airco**	473	−5.4	41.7	Basic chemicals	na	na	na	na	na	na	na
65	66	**Cabot**[f]	471	−4.1	31.0	Specialty metals	62	−4.7	30.1	13.2	264	20.0	23.5
66	55	**El Paso**	468	−18.8	10.7	Natural gas	−102	def	def	def	331	7.9	def
67	70	**National Starch**	467	3.8	67.5	Specialty chemicals	na	na	na	na	na	na	na
68	69	**International Flavors**	448	−0.7	100.0	Specialty chemicals	104	2.0	100.0	23.2	432	100.0	24.1
69	60	**Freeport-McMoRan**	435	−21.4	58.2	Agricultural chemicals	94	−36.6	130.6	21.6	282	17.0	33.3
70	74	**Polysar**	432	9.4	100.0	Basic chemicals	na	na	na	na	na	na	na
71	71	**Beatrice Foods**	419	−6.1	4.6	Food	9	−85.7	1.3	2.1	na	na	na
72	72	**Pfizer**	391	−7.2	11.3	Drugs	−1	def	def	def	421	11.2	def
73	77	**Liquid Air**	371	13.4	82.6	Basic chemicals	48	5.1	99.4	12.9	4[illegible]5	84.8	10.5
74	75	**Internorth**	341	−7.6	8.2	Natural gas	2	−91.1	1.0	0.6	na	na	na
75	—	**Henkel**	475	nc	100.0	Specialty chemicals	na	na	na	na	na	na	na
76	85	**H. B. Fuller**[l]	332	0.9	100.0	Specialty chemicals	25	−18.9	100.0	7.5	207	100.0	12.1
77	73	**Mississippi Chemical**[l]	326	−4.6	100.0	Farm cooperative	25	−67.2	100.0	7.7	375	100.0	6.7
78	78	**GAF**	311	−4.6	49.8	Specialty chemicals	50	−11.5	210.5	16.1	196	41.9	25.5
79	86	**Tyler**	302	9.0	34.6	Diversified chemicals	12	−49.8	23.0	3.9	162	35.0	7.4
80	83	**Rhône-Poulenc**	300	0	100.0	Specialty chemicals	na	na	na	na	na	na	na
81	89	**Big Three Industries**	283	6.9	36.9	Petroleum services	80	1.1	47.5	28.1	489	46.3	16.4
82	93	**Houston Natural Gas**[m]	278	12.3	8.7	Natural gas	32	17.5	8.5	11.5	398	17.0	8.0
83	91	**Petrolite**[k]	275	5.6	90.9	Specialty chemicals	48	9.9	91.0	17.5	161	80.3	29.8
84	80	**Terra Chemicals**	273	−13.9	100.0	Agricultural chemicals	na	na	na	na	na	na	na
85	79	**Upjohn**	268	−17.3	14.7	Drugs	−35	def	def	def	183	9.1	def
86	84	**Vulcan Materials**	263	−12.0	36.5	Nonmetallic minerals	44	−37.2	49.5	16.7	na	na	na
87	88	**Emhart**	253	−6.2	14.8	Machinery	23	−13.4	12.7	9.1	105	11.5	22.0
88	76	**American Petrofina**	252	−24.9	11.2	Petroleum	−7	def	def	def	207	19.1	def
89	92	**Soltex**	250	0	100.[illegible]	Basic chemicals	na	na	na	na	na	na	na
90	90	**SCM**[l]	249[e]	−5.5	13.2	Paint	22	−28.2	26.8	9.0	273	24.3	8.2
91	95	**Engelhard**	248[e]	3.4	12.3	Specialty metals	49	4.0	57.2	19.8	238	31.5	20.6
92	—	**Chemed**	233	−1.3	93.6	Specialty chemicals	32	4.3	91.3	13.5	105	63.3	29.9
93	86	**Martin Marietta**	222	−19.7	6.3	Aerospace	19	−60.1	11.9	8.6	239	9.3	7.9
94	97	**Loctite**	216	1.2	100.0	Specialty chemicals	26	99.8	100.0	12.0	200	100.0	13.0
95	96	**Beker Industries**	210	1.6	100.0	Agricultural chemicals	−9	def	def	def	304	100.0	def
96	98	**Stepan Chemical**	208	1.4	100.0	Specialty chemicals	13	−16.6	100.0	6.0	163	100.0	7.7
97	—	**Ferro**	205[e]	−13.3	34.5	Specialty materials	8	−42.9	22.7	4.1	114	32.7	7.4
98	99	**Getty**	202	−1.0	1.6	Petroleum	1	−92.9	0.1	0.5	na	na	na
99	100	**Agway**	194	−3.0	5.1	Farm cooperative	na	na	na	na	na	na	na
100	—	**Great Lakes Chemical**	168	12.9	100.0	Specialty chemicals	29	4.7	100.0	17.3	202	100.0	14.4

ended June 30, 1982. j Fiscal year ended Aug. 31, 1982. k Fiscal year ended Oct. 31, 1982. l Fiscal year ended Nov. 30, 1982. m Fiscal year ended July 31, 1982. **na** = not available. **nc** = not comparable with previous year. **def** = deficit.

2 Finances of the U.S. Chemical Industry

SHIPMENTS: Dollar volume in chemicals fell in 1982 for the first time in more than a decade

$ Billions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981-82	Annual change 1972-82
All manufacturing industries	$1886.0	$1994.6	$1851.0	$1727.2	$1523.4	$1358.4	$1185.6	$1039.1	$1017.5	$875.2	$756.3	−5%	10%
Chemicals and allied products	169.1	175.1	161.6	147.7	129.8	118.2	104.1	89.7	83.7	65.0	57.4	−3	11
Industrial chemicals[a]	54.4	60.7	56.4	52.3	44.8	41.5	35.6	29.4	26.6	19.0	16.6	−10	13
Drugs, soap, and toiletries	47.9	44.1	41.9	36.7	34.7	30.6	27.8	24.3	22.2	19.3	17.8	9	10
Petroleum and coal products	202.0	220.3	198.7	148.4	103.9	97.5	82.3	69.5	58.9	34.9	28.7	−8	22
Rubber and plastic products, nec	42.7	46.5	47.3	46.8	43.2	39.6	31.8	27.2	27.9	24.4	20.9	−8	7
Paper and allied products	78.2	79.5	72.6	65.2	57.0	52.1	48.2	41.7	41.8	32.8	28.3	−2	11

a Excluding pigments. nec = not elsewhere classified. **Source:** Department of Commerce

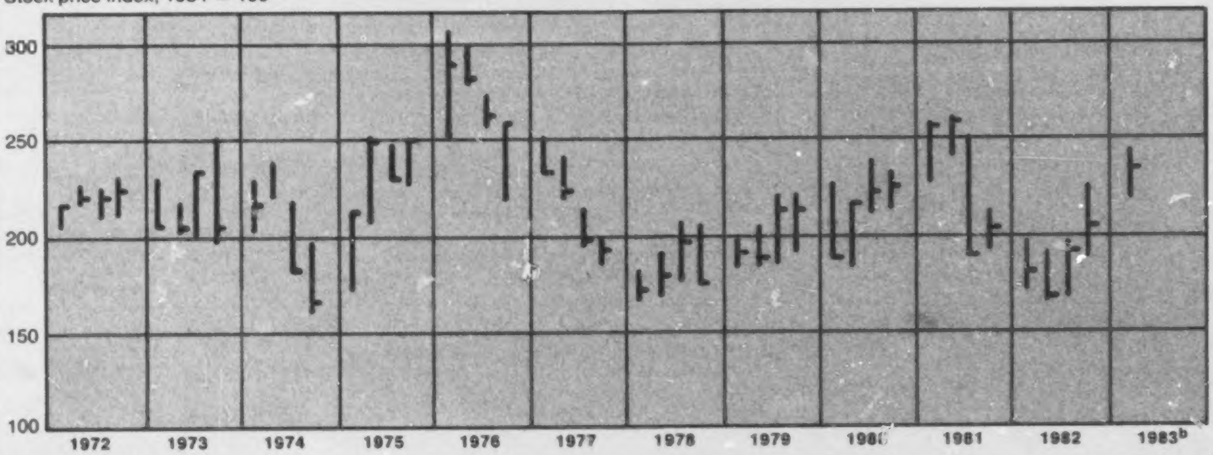
PRICES: Increases were small in 1982; some prices even dropped

Producer price indexes,[a] 1967 = 100	Annual average 1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981-82	Annual change 1972-82
All commodities	299.3	293.4	268.8	235.6	209.3	194.2	183.0	174.9	160.1	134.7	119.1	2%	10%
Industrial commodities	312.3	304.1	274.8	236.5	209.4	195.1	182.4	171.5	153.8	125.9	117.9	3	10
Chemicals and allied products	292.4	287.6	260.3	222.3	198.8	192.8	187.2	181.3	146.8	110.0	104.2	2	11
Industrial chemicals	353.0	363.3	324.0	264.0	225.6	223.9	219.3	206.9	151.7	103.4	101.2	−3	13
Prepared paint	262.9	249.8	235.3	204.4	192.3	182.4	174.4	166.9	145.7	122.2	118.0	5	8
Paint materials	304.6	300.1	273.9	241.2	212.7	205.9	189.8	177.2	152.3	113.2	104.1	1	10
Drugs and pharmaceuticals	210.1	193.5	174.5	159.4	148.1	140.5	134.0	126.6	112.7	104.3	103.0	9	7
Fats and oils, inedible	267.1	295.6	298.0	376.7	315.8	279.0	249.9	255.2	338.2	228.3	115.8	−10	9
Agricultural chemicals and chemical products	292.7	285.0	257.1	214.4	198.4	187.8	188.4	203.6	137.7	96.6	91.7	3	12
Plastic resins and materials	283.3	289.2	279.2	235.9	199.8	195.7	194.0	180.9	143.8	92.1	88.7	−2	12
Other chemicals and allied products	269.8	254.2	224.5	191.8	181.8	175.7	170.7	168.6	147.5	118.1	113.5	6	9
Rubber and plastics products	241.6	232.6	217.4	194.3	174.8	167.6	159.2	150.2	136.2	112.4	109.3	4	8

a Formerly called "wholesale price indexes." **Source:** Department of Labor

Past year has brought sharp recovery in chemical stock prices

Stock price index, 1954 = 100[a]



a C&EN weighted stock price index of Allied Corp., American Cyanamid, Celanese, Dow Chemical, Du Pont, Monsanto, and Union Carbide; weighted according to number of shares outstanding for each company. b First quarter.

INDUSTRY BALANCE SHEET: Little change overall in total assets or liabilities

Industrial chemicals and synthetics

Assets	1982	1981	Change
	($ billions)		
Current assets:			
Cash and time deposits in U.S.	$ 0.97	$ 0.94	3%
Marketable securities	1.33	1.11	20
Receivables	12.78	13.04	−2
Inventories	11.55	12.98	−11
Other current assets	2.72	1.97	38
Total	**29.33**	**30.04**	**−2**
Fixed assets:			
Plant, property, and equipment	70.50	71.87	9
Less: accumulated depreciation and depletion	35.00	31.97	9
Net fixed assets	**43.50**	**39.90**	**9**
Other assets, including investments and intangibles	**15.52**	**16.46**	**−6**
TOTAL ASSETS	**$88.35**	**$86.40**	2%

Source: Federal Trade Commission

Liabilities and stockholders' equity	1982	1981	Change
	($ billions)		
Current liabilities			
Accounts payable	$ 6.06	$ 6.71	−9%
Short-term loans	1.32	1.47	−10
Accrued income taxes	0.52	0.74	−30
Current portion of long-term debt	0.75	0.63	19
Other current liabilities	7.72	6.69	15
Total	**16.39**	**16.24**	**1**
Long-term debt	**21.03**	**21.41**	**−2**
Deferred taxes, minority interest, and other noncurrent liabilities	**6.79**	**6.21**	**9**
TOTAL LIABILITIES	**44.21**	**43.87**	**1**
Stockholders' equity			
Capital stock and other capital	17.44	15.55	12
Retained earnings	26.70	26.98	−1
TOTAL STOCKHOLDERS' EQUITY	**44.14**	**42.53**	**4**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$88.35**	**$86.40**	2%

DEBT RATIOS: Down slightly in 1982 for chemical companies but still higher than usual

$ Billions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$21.0	$21.4	$16.8	$14.8	$13.6	$12.3	$11.8	$10.2	$7.8	$7.2	$7.6
Stockholders' equity	$44.1	$42.5	$39.8	$32.3	$29.3	$26.3	$25.0	$22.8	$20.5	$18.7	$18.5
Debt ratio[a]	32.2%	33.5%	29.6%	31.4%	31.8%	31.9%	32.0%	30.8%	27.6%	27.8%	29.2%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$37.2	$36.9	$28.3	$24.9	$23.5	$21.1	$19.4	$16.8	$12.8	$10.7	$11.5
Stockholders' equity	$93.2	$89.9	$79.5	$67.4	$60.8	$54.9	$50.8	$45.7	$40.9	$36.7	$36.1
Debt ratio[a]	28.5%	29.1%	26.3%	27.0%	27.9%	27.8%	27.6%	26.9%	23.8%	22.6%	24.2%
ALL MANUFACTURING											
Long-term debt	$292.9	$266.5	$236.2	$204.8	$182.0	$167.3	$153.6	$145.2	$130.1	$112.9	$118.3
Stockholders' equity	$782.3	$762.3	$699.7	$624.0	$560.8	$511.7	$475.3	$435.5	$408.4	$368.0	$353.1
Debt ratio[a]	27.2%	25.9%	25.2%	24.7%	24.5%	24.6%	24.4%	25.0%	24.2%	23.5%	25.1%

[a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Note:** Because of changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. **Source:** Federal Trade Commission

CASH FLOW: Companies trimmed working capital and made a big cut in debt last year

$ Millions, % of total	1982		1981		1980		1979		1978	
SOURCES OF FUNDS										
Net income	$ 2,892	17.9%	$ 4,358	18.2%	$ 3,981	33.2%	$ 3,801	36.3%	$3085	33.6%
Depreciation and depletion	5,073	31.5	4,267	17.9	3,818	31.8	3,602	34.4	3197	34.8
Deferred taxes	694	4.3	1,012	4.2	679	5.7	427	4.1	353	3.8
Other internal sources	2,167	13.4	1,833	7.7	815	6.8	1,093	10.5	930	10.1
Long-term debt	3,466	21.5	7,493	31.4	2,079	17.3	1,210	11.6	1545	16.8
Stock	1,834	11.4	4,931	20.6	630	5.2	322	3.1	84	0.9
TOTAL	**$16,126**	**100.0%**	**$23,894**	**100.0%**	**$12,002**	**100.0%**	**$10,454**	**100.0%**	**$9194**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 2,003	12.4%	$ 1,845	7.7%	$ 1,603	13.4%	$ 1,474	14.1%	$1317	14.3%
Capital expenditures	8,506	52.7	8,344	34.9	7,027	58.5	5,633	53.9	5080	55.3
Additions to working capital	−1,842	−11.4	3,759	15.7	1,057	8.8	1,075	10.3	863	9.4
Reduction of long-term debt	4,335	26.9	1,493	6.3	1,119	9.3	1,042	10.0	879	9.5
Other applications	3,124	19.4	8,453	35.4	1,196	10.0	1,230	11.7	1054	11.5
TOTAL	**$16,126**	**100.0%**	**$23,894**	**100.0%**	**$12,002**	**100.0%**	**$10,454**	**100.0%**	**$9194**	**100.0%**

Note. Data are totals for 15 major chemical companies: Allied, American Cyanamid, Celanese, Diamond Shamrock, Dow Chemical, Du Pont, Ethyl, Hercules, Monsanto, Olin, Pennwalt, Rohm & Haas, Stauffer Chemical, Union Carbide, and Williams Cos. **Source:** Company annual reports

FINANCIAL ANALYSIS: Many analytical measures deteriorated last year

	Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D spending as % of sales	Sales as % of assets	Net plant as % of gross plant
								as % of sales	as % of net plant			
SALES OVER $1 BILLION												
Air Products[g]	6.8%	3.6%	36.1%	22.1%	18.9%	$ 83	21.7%	22.1%	23.2%	2.4%	72.3%	61.5%
American Cynamid	3.8	3.2	24.7	35.3	26.5	86	63.6	5.0	13.2	5.2	115.2	49.8
Celanese	0.2	0.1	40.5	23.3	22.8	83	1340.0	9.0	17.1	3.3	107.0	43.0
Dow Chemical	3.2	2.3	41.0	52.2	44.5	188	101.8	7.8	13.9	4.3	89.9	53.2
Ethyl	5.8	5.5	30.9	25.4	11.0	115	36.2	22.8	55.3	2.4	138.9	55.0
FMC	4.3	4.4	22.3	33.4	13.6	109	37.5	8.0	22.0	3.2	126.5	58.3
B. F. Goodrich	def	def	33.2	16.3	13.7	100	def	5.0	11.1	2.0	145.1	59.6
W. R. Grace	5.2	5.4	37.2	18.9	5.3	75	40.9	9.1	20.7	1.0	124.7	64.3
Hercules	3.5	3.0	28.6	23.5	22.3	114	65.5	6.7	17.9	2.9	123.4	44.4
International Minerals[h]	7.8	4.9	30.4	14.3	9.1	186	56.6	10.4	13.7	na	80.3	63.3
Monsanto	5.2	8.3	22.3	29.1	19.9	121	48.0	10.6	20.3	4.0	104.1	52.2
National Distillers	4.3	4.5	18.0	na	na	na	102 5	3.6	13.4	na	149.1	52.0
Olin	3.5	2.5	26.7	6.1	10.2	104	44.4	7.6	16.5	2.6	111.4	47.2
PPG Industries	4.7	3.5	21.9	22.3	20.6	89	52.3	13.7	22.6	3.9	100.8	59.5
Rohm & Haas	4.7	4.3	22.9	37.1	27.3	158	41.9	6.9	23.0	5.0	133.9	42.1
Stauffer Chemical	7.7	4.4	28.3	13.2	9.8	148	50.0	10.9	14.8	3.8	73.9	60.5
Union Carbide	3.4	2.2	32.0	33.1	30.1	88	75.8	13.0	18.5	2.6	85.4	58.9
Williams Cos.	1.8	1.0	39.1	na	na	93	120.0	10.2	11.4	na	71.4	66.7
Witco Chemical	2.3	3.5	33.1	14.3	13.9	168	56.7	4.1	18.5	na	197.1	54.7
MEDIAN 1982	**4.3%**	**3.5%**	**30.4%**	**23.3%**	**18.9%**	**$109**	**52.3%**	**9.0%**	**17.9%**	**3.2%**	**111.4%**	**55.0%**
MEDIAN 1981	**5.2%**	**4.8%**	**27.4%**	**24.2%**	**17.1%**	**$120**	**36.8%**	**9.9%**	**21.3%**	**2.8%**	**119.1%**	**57.7%**
SALES FROM $150 MILLION TO $1 BILLION												
Chemed	6.7	14.0	58.3	14.9	13.8	na	81.0	2.0	16.2	0.9	149.7	63.1
Crompton & Knowles	1.8	2.9	24.4	21.8	23.0	91	100.0	1.7	10.9	2.0	165.1	61.2
Essex Chemical	4.0	4.0	61.0	na	na	170	35.9	16.3	41.0	1.5	117.7	67.5
First Mississippi[h]	10.4	5.8	24.5	18.0	na	193	21.6	30.4	36.9	na	56.5	67.9
Freeport-McMoRan	12.0	4.2	39.6	na	na	150	46.4	64.2	36.4	na	45.1	68.4
H. B. Fuller[i]	2.6	3.8	35.1	32.6	52.6	83	27.9	5.1	22.9	2.0	160.1	68.5
GAF	2.0	2.3	40.2	12.0	7.0	139	82.8	2.8	9.2	1.1	133.1	61.3
Great Lakes Chemical	9.4	6.7	21.9	17.7	na	na	23.8	10.9	16.8	3.4	86.4	66.7
International Flavors	14.1	12.4	0	66.9	51.7	124	59.0	6.3	20.9	6.8	103.8	58.8
Liquid Air	6.1	4.0	33.0	38.3	37.4	na	76.4	13.1	16.6	1.5	83.6	64.0
Loctite[h]	7.3	7.7	11.5	41.1	45.2	87	34.8	5.0	24.5	2.6	108.3	68.5
Lubrizol	5.9	6.0	4.0	59.8	42.6	190	88.9	6.4	17.9	4.4	126.3	58.8
Nalco Chemical	10.0	11.1	4.8	21.3	24.1	140	68.9	8.7	28.9	5.2	138.5	52.7
Pennwalt	2.6	2.4	31.3	19.1	18.6	100	95.1	8.0	22.3	3.2	125.9	52.0
Petrolite[j]	9.7	10.8	6.6	20.9	21.4	na	38.6	7.8	29.5	3.1	151.1	52.0
Reichhold Chemicals	0.6	1.0	25.8	16.6	13.1	182	134.0	2.5	12.9	0.8	222.1	58.1
Stepan	4.4	4.8	31.4	na	na	227	21.7	7.7	21.3	3.2	127.6	59.4
MEDIAN 1982	**6.1%**	**4.8%**	**25.8%**	**21.1%**	**22.2%**	**$140**	**59.0%**	**7.7%**	**21.3%**	**2.6%**	**126.3%**	**61.3%**
MEDIAN 1981	**7.4%**	**7.8%**	**23.4%**	**20.5%**	**23.8%**	**$141**	**36.8%**	**5.9%**	**20.5%**	**2.5%**	**133.6%**	**61.0%**

a Net income as a percentage of sales. b Net income as a percentage of current assets plus gross plant. c Consolidated sales only. d Foreign identifiable assets as a percentage of total assets. e Thousands of dollars. f Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. g For fiscal year ended Sept. 30, 1982. h For fiscal year ended June 30, 1982. i For fiscal year ended Nov. 30, 1982. j For fiscal year ended Oct. 31, 1982. **na** = not available. **def** = deficit. **Note:** Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible.

CHEMICAL CAPITAL SPENDING: Many companies trim budgets drastically this year

$ Millions	1983[a]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Air Products	$ 275	$ 347	$ 323	$ 364	$ 246	$ 200	$ 143	$ 162	$ 151	$ 110	$ 67
American Cyanamid	190	171	181	196	235	251	235	232	204	139	83
Celanese	110	275	414	253	245	248	243	223	208	220	159
Diamond Shamrock	360	540	521	387	266	319	390	334	183	201	103
Dow Chemical	750	829	1176	1184	1268	1075	1163	1200	935	890	415
Du Pont[b]	1100	1300	1420	1297	864	714	704	876	1036	1008	781
Ethyl	100	368	141	156	123	96	88	89	69	75	35
W. R. Grace	495	560	657	658	514	313	279	234	309	303	174
Hercules	200	165	167	229	186	116	127	150	151	217	144
Monsanto	700	673	668	781	566	480	607	647	528	313	205
Olin	160	139	186	172	161	163	208	166	99	67	78
Rohm & Haas	85	126	182	93	68	66	79	110	106	106	73
Stauffer Chemical	170	177	239	246	239	201	193	199	199	83	45
Union Carbide	950	1179	1186	1129	831	688	805	965	862	517	289
TOTAL	**$5645**	**$6849**	**$7461**	**$7145**	**$5812**	**$4930**	**$5264**	**$5587**	**$5040**	**$4249**	**$2651**
ANNUAL CHANGE	**−18%**	**−7%**	**4%**	**23%**	**18%**	**−6%**	**−6%**	**11%**	**19%**	**60%**	**29%**

a Planned. b Excludes Conoco. **Note:** Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. **Source:** Company data

The much talked about last year's recession took its toll on capital spending by the U.S. chemical industry, driving it down from year-earlier levels as companies moved to protect financial resources at the expense of investment in new plant. Moreover, the recession drove down demand for chemicals so far that its effects are spilling over into this year as well. Chemical companies realize that there is so much shut-down capacity that they will not have to build plants for many products anytime in the immediate future. For some products, in fact, producers are saying that there is enough idle capacity to last well into the late 1980s.

An update of C&EN's annual worldwide capital spending survey by 14 major U.S. chemical firms shows that spending on new plant and equipment in 1983 will be about $5.6 million, 18% below levels for last year. Capital spending in 1982 for the same companies decreased 7% from its peak of $7.5 billion in 1981.

C&EN's survey is in sharp contrast with the government's estimates of capital spending by the much broader chemicals and allied products category. The Commerce Department estimates that capital spending in 1983 will increase 3% after a 2% drop for 1982. This means, according to Commerce Department figures, that capital spending in 1983 will total $13.69 billion, compared to $13.27 billion in 1982, for chemicals and allied products.

For spending by wholly owned foreign affiliates of U.S. chemical companies, the Commerce Department projects an increase of almost 4% in 1983 to about $3.0 billion from $2.9 billion in 1982, moving back to its level in 1981.

Many of the plant and equipment projects that had been planned in recent years are finished, and there are few plans to build more at this time. This is evident in the Conference Board's survey of appropriations for capital spending for chemicals and allied products. According to the Conference Board, in spite of the decrease in capital spending in 1982, the backlog of unspent appropriations also fell. The backlog at the end of 1982 totaled $7.39 billion, 22% below the backlog at the end of fourth-quarter 1981.

According to C&EN's survey, chemical capital spending as a percentage of sales in 1982 rose to 10.5% from 10.2% in 1981. The figure was propped up somewhat by the decline in sales last year in the chemical industry. In 1983, on the other hand, C&EN projects that capital spending will be only about 8% of sales, as spending on new plant and equipment continues to decline but sales begin their recovery.

2 Finances of the U.S. Chemical Industry

INDUSTRY CAPITAL SPENDING: Small increase planned for chemicals and allied products

$ Billions	1983[a]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Chemicals	$ 13.69	$ 13.27	$ 13.60	$ 12.60	$10.78	$ 8.46	$ 8.14	$ 8.12	$ 7.63	$ 6.48	$ 4.24
Iron and steel	2.56	3.47	3.17	3.29	3.09	2.52	2.79	3.04	3.03	1.94	1.25
Nonferrous metals	2.38	2.71	3.46	3.11	2.39	2.11	1.88	1.97	2.18	2.04	1.30
Paper	6.09	5.97	6.72	6.80	5.55	3.99	3.59	3.11	2.96	2.90	2.00
Petroleum	24.57	26.69	26.56	20.69	16.21	13.95	12.70	10.76	9.59	7.31	4.68
Rubber	1.84	1.71	1.77	1.73	2.17	2.10	1.66	1.32	1.15	1.56	1.55
Stone, clay, glass	2.43	2.61	3.14	3.82	3.94	3.10	2.23	1.88	1.67	1.64	1.58
All manufacturing	115.90	119.68	126.79	115.81	98.68	79.72	69.22	59.95	54.92	53.21	42.37

[a] Estimate. **Source:** Department of Commerce

Chemical industry has been trimming its backlog of unspent capital funds

$ Billions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Chemicals	$ 7.4	$ 9.4	$ 9.6	$ 8.5	$ 7.2	$ 7.4	$ 7.1	$ 6.9	$ 6.6	$ 4.9	$ 2.9
Iron and steel	2.8	5.4	3.9	4.5	4.0	3.6	4.7	5.4	5.8	2.4	1.9
Nonferrous metals	3.2	3.7	3.7	2.9	2.7	2.9	2.4	2.2	2.7	2.2	1.1
Paper	5.0	5.1	4.0	4.2	3.2	2.6	2.0	2.7	2.9	1.7	1.1
Petroleum, coal	22.6	29.7	26.7	16.1	14.6	15.0	12.2	14.1	12.8	7.1	4.3
Rubber	1.0	0.9	1.0	0.9	0.9	0.8	0.7	0.6	0.7	0.9	0.8
Stone, clay, glass	1.7	1.9	2.0	2.3	2.4	2.0	1.5	1.4	1.7	1.5	0.8
All manufacturing	70.4	92.7	91.9	76.7	63.4	56.5	47.5	46.4	49.8	37.1	23.3

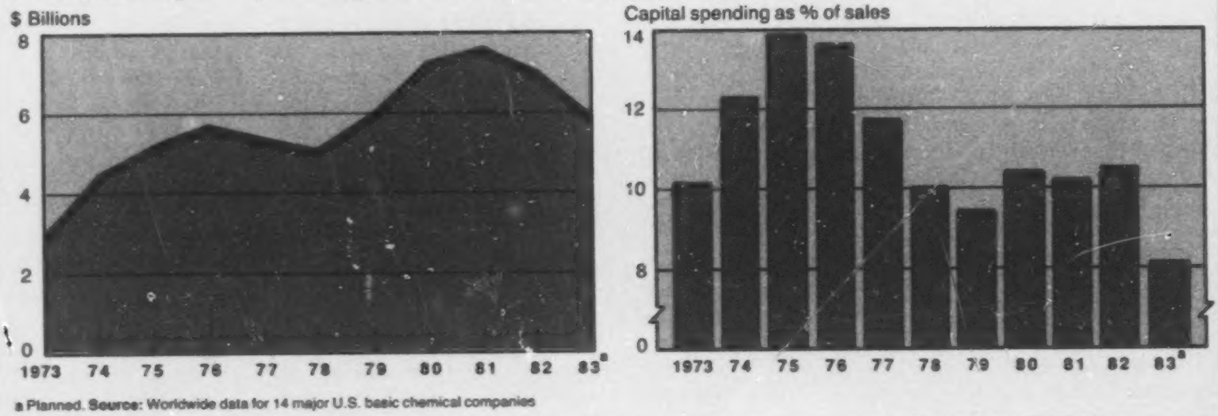
Note: Figures are for fourth quarter each year. **Source:** Conference Board

Overseas investment by U.S. chemical firms has shown little change recently

$ Billions[a]	1983[b]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Chemicals and allied products	$ 3.0	$ 2.9	$ 3.0	$ 3.0	$ 2.6	$ 1.9	$ 2.0	$ 2.7	$ 2.5	$ 2.1	$1.4
Metals, primary and fabricated	1.0	0.9	0.8	0.9	0.6	0.6	0.5	0.7	0.7	0.7	0.8
All manufacturing	17.2	16.6	19.2	19.5	15.4	12.0	10.5	10.9	11.3	11.6	9.2
Petroleum	17.2	17.7	15.6	14.8	11.0	9.5	6.9	7.9	8.9	7.8	6.4

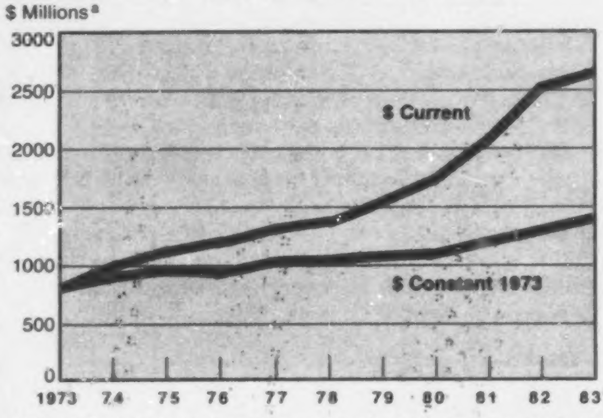
[a] By majority-owned foreign affiliates of U.S. companies; data after 1976 are not consistent with earlier years. [b] Planned. **Source:** Department of Commerce

Chemical capital spending, down for second year, drops to 10-year low relative to sales

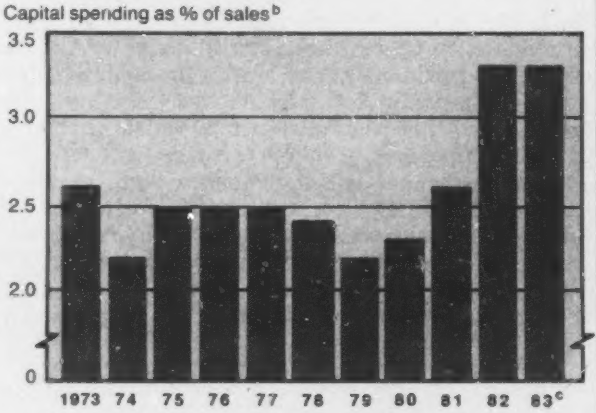


a Planned. **Source:** Worldwide data for 14 major U.S. basic chemical companies

Chemical companies' spending on R&D will make a moderate gain this year . . .



. . . but will hold steady relative to company sales volume



a R&D spending by basic chemical companies. b By basic chemical companies. c Estimates.
Sources: Worldwide data for 15 U.S. basic chemical companies, Battelle Columbus Laboratories, C&EN estimates

Although support for research and development by the U.S. chemical industry is not increasing so fast as it was just a year ago, it has not dwindled as has capital spending.

C&EN's survey of 15 basic chemical companies shows that R&D spending in 1983 will increase only 7% to about $2.7 billion from about $2.5 billion in 1982. Spending in 1982 was up 20% from 1981's $2.1 billion. In fact, the planned increase for 1983 is the lowest since 1978, when R&D spending went up only 6%.

The small increase in 1983 may be only a pause; companies continue to say that they have to refine process and product technology to meet increased raw material and energy costs. Thus, once earnings rebound, there may be a return to the larger annual increases that occurred in the past few years. Between 1978 and 1982, spending by the 15 chemical companies surveyed increased at an average annual rate of about 16%. After adjusting for inflation, however, the increase was just 7% per year. This year, adjusting for expected inflation, R&D spending will increase a mere 2%.

In 1982, R&D spending by the chemical industry rose to 3.3% of sales, the highest it has been in more than a decade. However, the increase from 2.5% the year before came while sales in the industry were falling. For 1983, C&EN estimates that spending as a percentage of sales will hold around the 3.3% level as both spending and sales increase at about equal rates.

CHEMICAL R&D SPENDING: Most budgets are higher, but increases are often moderate

$ Millions	1983[a]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Air Products	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	$ 16	$ 11	$ 8
American Cyanamid	200	181	164	142	124	108	96	83	73	64	52
Celanese	100	102	104	94	92	83	77	70	64	58	49
Diamond Shamrock	46	48	53	45	37	32	26	24	20	14	12
Dow Chemical	480	460	404	314	269	232	203	188	167	149	118
Du Pont[b]	890	790	575	485	415	377	367	353	336	344	286
Ethyl	39	39	38	34	29	26	28	25	28	25	22
W. R. Grace	71	62	55	45	42	37	32	28	30	32	28
Hercules	68	71	61	53	47	40	37	35	30	30	25
Monsanto	284	256	221	204	161	136	132	114	116	87	82
Olin	48[c]	47	39	31	26	25	25	25	24	19	na
Pennwalt	34	31	27	24	22	23	21	19	16	14	13
Rohm & Haas	94[c]	92	77	67	54	49	45	43	45	39	32
Stauffer Chemical	64	62	51	44	37	34	33	29	24	20	17
Union Carbide	240	240	201	166	161	156	156	143	120	94	77
TOTAL	**$2698**	**$2518**	**$2102**	**$1778**	**$1540**	**$1381**	**$1302**	**$1198**	**$1109**	**$1000**	**$821**
ANNUAL CHANGE	**7%**	**20%**	**18%**	**15%**	**12%**	**6%**	**9%**	**8%**	**11%**	**20%**	**5%**

a Planned. b Excludes Conoco. c C&EN estimate. **Source:** Company data

2 Finances of the U.S. Chemical Industry

The financial strains of a severe business recession are clearly visible spread across the pages of the annual reports issued by chemical companies for 1982. And so they show up, as well, in the data for the 33 individual chemical companies that are tabulated (together with figures for 16 pharmaceutical firms) on this and the following four pages.

Nearly four times as many chemical companies recorded lower sales last year as turned in a gain. And although the industry was not plagued with the net losses that swept through the steel or auto industries, only a couple of chemical companies showed any gain in earnings. For more than two thirds of the companies, in fact, last year's earnings trailed those of 1980 as well as those of 1981.

Balance sheets, too, showed the impact of financial stress. For nearly half the chemical companies, total assets surprisingly were down last year. And for a quarter of the companies, so was net worth.

The pharmaceutical companies, on the other hand, firmly demonstrated their traditional immunity to the vicissitudes of the business cycle. Only a couple of the 16 companies listed earned less in 1982 than during the preceding year. About two thirds of them, moreover, even were able to improve either their return on stockholders' equity or their profit margins—or both.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). **Per cent of sales:** net income divided by net sales. **Per cent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share of common stock.

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
CHEMICALS														
Air Products & Chemicals														
1982[a]	$1,568,916	$105,654[b]	$2,118,882	1.2	$1,497,162	$346,680	$867,565	6.7%	12.2%	$3.68[b]	$0.80	2.5%	$41⅛–23⅝	8.8
1981[a]	1,570,115	126,039	1,871,986	1.2	1,301,922	323,465	769,134	8.0	16.4	4.42	0.80	1.9	48⅞–34	9.4
1980[a]	1,420,759	115,502	1,744,392	1.3	1,182,567	364,013	658,596	8.1	17.5	4.07	0.80	1.8	54¼–32¼	10.6
1979[a]	1,229,894	97,540	1,415,024	1.3	945,013	246,050	563,702	7.9	17.3	3.45	0.65	2.1	37¼–23¾	8.8
Allied Corp.														
1982	$6,167,000	$280,000[c]	$6,140,000	1.3	$2,858,000	$524,000	$3,661,000	4.5%	7.6%	$6.46[c]	$2.40	6.5%	$45⅝–28¾	5.7
1981	6,407,000	343,000[d]	5,205,000	1.4	2,866,000	609,000	2,352,000	5.4	14.6	9.03[d]	2.35	4.8	59⅞–39	5.5
1980	5,519,000	303,000[e]	4,475,000	1.3	2,384,000	533,000	1,861,000	5.5	16.3	8.59[e]	2.15	4.3	61¾–39	5.9
1979	4,332,391	201,080[f]	4,159,798	1.1	2,168,816	408,668	1,377,701	4.6	14.6	6.84[f]	2.00	5.1	49½–28½	5.7
American Cyanamid Co.														
1982	$3,453,674	$132,127	$2,985,004	2.0	$1,296,204	$171,047	$1,526,390	3.8%	8.7%	$2.74	$1.75	5.7%	$37½–24⅜	11.3
1981	3,649,073	197,054	3,049,917	1.9	1,325,063	180,697	1,513,457	5.4	13.0	4.11	1.675	5.5	36½–24½	7.4
1980	3,453,934	159,195	2,900,289	1.8	1,328,691	195,819	1,419,073	4.6	11.2	3.32	1.60	5.5	38–20⅝	8.8
1979	3,186,998	168,495	2,810,725	1.6	1,303,308	235,416	1,331,130	5.3	12.7	3.52	1.60	5.3	36⅛–23¾	8.5
Beker Industries Corp.														
1982	$210,185	($5,256)[g]	$304,073	0.8	$178,796	$18,534	$102,015	...	...	($0.44)[g]	0.00	0.0	$8⅝–3⅞	...
1981	206,813	1,254[h]	342,935	1.0	189,135	65,486	115,289	0.6%	1.1%	0.11[h]	0.00	0.0	25–7½	147.7
1980	248,079	25,691[i]	286,821	1.3	133,850	32,150	119,748	10.4	21.5	2.21[i]	0.00	0.0	25–8⅞	7.7
1979	227,790	12,910[j]	241,476	1.2	111,765	5,864	91,760	5.7	1.41	1.12[j]	0.00	0.0	15¾–3⅝	8.6

a Fiscal year ends Sept. 30. b Excludes extraordinary gain on debt-for-equity exchange of $2.8 million ($0.10 per share) and credit for cumulative effect of change in accounting principle for investment tax credit of $61.9 million ($2.16 per share). c Excludes nonrecurring net loss of $8 million ($0.2[illegible] per share). d Excludes nonrecurring net gain of $5 million ($0.14 per share). e Excludes nonrecurring net loss from estimated plant shutdown and disposal costs of $14 million ($0.44 per share). f From continuous operations; excludes net losses from discontinued businesses of $164.8 million ($5.75 per share) and nonrecurring net loss of $25.4 million ($0.89 per share). g Net loss; excludes net loss from discontinued operations and their disposition of $8.0 million ($0.68 per share). h Excludes net loss from discontinued operations of $6.1 million ($0.52 per share). i Excludes net earnings from discontinued operations of $3.2 million ($0.28 per share). j Excludes net gain on sale of 50% interest in phosphate assets of $23.5 million ($2.04 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Money figures in thousands of dollars unless otherwise indicated														
Big Three Industries														
1982	$767,785	$ 86,812	$1,055,313	3.0	$773,777	$162,293	$609,792	11.3%	14.2%	$2.05	$0.72	3.3%	$28½–15⅛	10.6
1981	823,280	108,854	1,015,259	2.7	580,709	158,234	555,765	13.2	19.6	2.57	0.60	1.9	37⅝–25	12.2
1980	659,121	86,604	815,048	2.2	583,772	142,542	472,607	13.1	18.3	2.05	0.47[a]	1.7	36⅛–18⅞	13.4
1979	509,449	62,859	700,052	2.3	483,921	79,710	404,137	12.3	15.6	1.56	0.42	2.2	22¼–15¾	12.2
Cabot Corp.														
1982[b]	$1,587,658	$ 88,007	$1,300,553	2.2	$664,434	$138,342	$624,069	5.5%	14.1%	$2.77	$0.92	4.4%	$25½–16⅛	7.5
1981[b]	1,622,755	110,167	1,238,729	2.2	595,234	192,348	586,226	6.8	18.8	3.50	0.86	2.9	35½–23⅞	8.5
1980[b]	1,403,743	94,024[c]	1,138,683	2.0	456,507	117,705	497,546	6.7	18.9	3.00[c]	0.67	2.6	36⅜–14¾	8.5
1979[b]	1,122,391	70,445	918,431	2.0	401,638	68,266	358,031	6.3	19.7	2.23	0.47	3.5	16⅝–10⅛	5.9
Celanese Corp.														
1982	$3,062,000	($34,000)[d]	$2,862,000	1.9	$1,608,000	$275,000	$1,131,000	. . .	. . .	($2.45)[d]	$4.00	7.9%	$59⅞–41¼	. . .
1981	3,752,000	144,000	2,991,000	2.0	1,518,000	414,000	1,233,000	3.8%	11.7%	9.01	3.85	6.4	69¼–51⅝	6.7
1980	3,348,000	122,000	2,633,000	2.0	1,197,000	253,000	1,101,000	3.6	11.1	8.20	3.50	6.8	62⅝–3[illegible]	6.2
1979	3,146,000	141,000	2,374,000	1.8	1,150,000	245,000	1,033,000	4.5	13.6	9.52	3.10	7.0	48¾–[illegible]	4.6
Crompton & Knowles Corp.														
1982	$213,250	$5,199	$117,902	2.6	$33,055	$3,582	$59,320	2.4%	8.8%	$1.44	$1.04	6.6%	$19⅝–12⅛	9.1
1981	243,412	8,571	132,197	2.3	32,668	6,699	63,606	3.5	13.5	2.51	0.95	6.1	18⅛–12⅞	6.2
1980	241,776	7,666	135,619	2.5	34,731	9,623	58,935	3.2	13.0	2.22	0.80	5.8	16⅝–10⅞	6.2
1979	239,638	7,075	131,433	2.2	28,822	7,895	55,212	3.0	12.8	2.03	0.69	6.6	12¼–8⅝	5.1
Diamond Shamrock Corp.														
1982	$3,177,379	$149,543[e]	$3,123,191	1.6	$2,114,436	$612,698	$1,336,409	4.7%	11.2%	$2.37[e]	$1.76	8.3%	$25¾–16½	8.9
1981	3,376,215	230,156[f]	2,933,550	1.9	1,726,458	520,917	1,266,900	6.8	18.2	3.60[f]	1.70	5.4	39⅝–23¾	8.6
1980	3,143,040	201,214	2,707,284	2.1	1,600,250	381,036	1,155,950	6.4	17.4	3.66	1.62	5.2	35⅞–23⅛	8.5
1979	2,356,858	178,123	2,329,892	1.9	1,382,931	256,564	931,267	7.6	19.1	3.37	1.51	6.0	31½–19	7.5
Dow Chemical Co.														
1982	$10,618,000	$342,000[g]	$11,612,000	1.8	$5,961,000	$ 829,000	$4,845,000	3.2%	7.1%	$1.77[g]	$1.80	7.4%	$28⅞–19⅝	13.7
1981	11,873,000	564,000	12,268,000	1.7	6,174,000	1,176,000	4,663,000	4.8	12.1	3.00	1.80	5.8	39–23⅝	10.4
1980	10,626,000	753,000[h]	11,429,000	1.5	5,672,000	1,164,000	4,331,000	7.1	17.4	4.14[h]	1.60	4.7	39¼–28¼	8.2
1979	9,255,387	734,000[i]	10,144,745	1.4	5,236,404	1,267,710	3,789,746	7.9	19.4	4.05[i]	1.45	4.9	34⅞–24⅜	7.3
E. I. du pont de Nemours & Co.														
1982	$33,331,000	$ 894,000	$24,343,000	1.7	$14,004,000	$3,295,000	$10,850,000	2.7%	8.2%	$3.75	$2.40	6.5%	$44⅜–30	9.9
1981	22,810,000	1,081,000[j]	23,829,000	2.0	12,722,000	2,389,000	10,458,000	4.7	10.3	5.81[j]	2.75	6.0	56–35¾	7.9
1980	13,652,000	716,000	9,560,000	2.3	4,414,000	1,279,000	5,690,000	5.2	12.6	4.83	2.75	6.8	49½–31⅛	8.3
1979	12,571,800	938,900	8,918,700	2.5	3,942,400	864,000	5,290,600	7.5	17.7	6.42	2.75	6.5	48¼–37	6.6
Ethyl Corp.														
1982	$1,614,626	$94,166	$1,458,534	2.2	$666,186	$ 91,915	$766,175	5.8%	12.3%	$2.34	$0.75	5.7%	$17⅛–9	5.6
1981	1,757,195	90,891	1,194,630	2.2	658,282	140,520	683,001	5.2	13.3	2.28	0.75	5.3	17¼–10⅞	6.2
1980	1,740,627	82,397[k]	1,138,233	2.4	602,029	156,388	631,831	4.7	13.0	2.05[k]	0.75	5.1	18¼–11⅛	7.1
1979	1,656,977	97,515	1,070,968	2.8	512,981	122,878	536,671	5.9	18.2	2.47	0.675	5.3	15–10½	5.2
Ferro Corp.														
1982	$595,830	$10,277[l]	$345,922	2.0	$133,318	$22,650	$161,945	1.7%	6.3%	$1.37[l]	$1.20	4.9%	$30½–18½	17.9
1981	702,213	25,503	389,405	2.1	135,587	24,243	222,441	3.6	11.5	3.30	1.20	4.6	31½–20¾	7.9
1980	695,580	29,019	430,472	2.0	134,563	31,505	220,597	4.2	13.2	3.77	1.20	5.8	24¼–17	5.5
1979	591,930	30,912	387,703	1.8	115,831	33,132	200,625	5.2	15.4	4.07	1.14	4.7	29⅜–19	5.9
First Mississippi Corp.														
1982[m]	$222,977	$23,212[n]	$394,587	1.0	$183,994	$67,882	$145,407	10.4%	16.0%	$1.11	$0.24	2.2%	$ 16–6	9.9
1981[m]	357,697	29,704	318,926	1.5	117,244	58,277	138,384	8.3	21.5	1.38	0.23	1.2	26⅛–13⅛	14.2
1980[m]	242,690	21,154	236,579	2.1	83,525	37,202	113,672	8.7	18.6	0.98	0.18	0.9	30¾–7½	19.5
1979[m]	178,400	4,661	200,370	2.8	63,942	17,046	95,073	2.6	4.9	0.22	0.16	2.0	11¾–4	35.8
W. R. Grace & Co.														
1982	$6,127,600	$319,500[o]	$4,854,300	1.7	$2,706,400	$559,500	$2,136,600	5.2%	15.0%	$6.62[o]	$2.70	7.2%	$46¼–28½	5.6
1981	6,520,800	361,300[p]	4,947,100	1.5	2,528,600	656,900	1,986,600	5.5	18.2	7.5[illegible][p]	2.45	5.0	59⅝–38½	6.5
1980	6,101,300	283,800[q]	4,281,500	1.5	2,162,700	657,400	1,713,100	4.7	16.6	6.0[illegible][q]	2.175	4.5	53½–32⅝	7.9
1979	5,266,629	222,580[r]	3,680,847	1.6	1,629,361	477,688	1,524,276	4.2	14.6	5.02[r]	1.975	5.9	41¼–25⅝	6.7
Great Lakes Chemical Corp.														
1982	$169,703	$13,945	$202,058	2.2	$113,659	$19,143	$120,913	8.2%	11.5%	$1.93	$0.52	1.6%	$40¼–24⅞	16.9
1981	150,333	18,031	170,198	1.9	98,580	22,777	108,873	12.0	16.6	2.51	0.44	0.9	58½–36¼	18.9
1980	126,705	18,948	118,407	3.2	61,747	20,496	93,258	15.0	20.3	2.67	0.36	0.8	51¼–35⅝	16.3
1979	122,491	18,606	99,323	2.8	48,802	18,315	75,457	15.2	24.7	2.65	0.28	0.9	39¼–22½	11.7

a Plus 5% stock dividend. b Fiscal year ends Sept. 30. c From continuing operations; excludes net income from discontinued operations of $12.3 million ($0.39 per share) and net gain on sale of machinery division of $46.4 million ($1.49 per share). d Net loss; includes special charge related to 40% equity in Mexican affiliate of $39 million ($2.50 per share). e Excludes extraordinary net gain from debt-for-equity exchange of $35.5 million ($0.57 per share). f From continuing operations; excludes net loss from operations and disposal of plastics and animal nutrition businesses of $108.9 million ($1.74 per share). g Includes pretax gain on sales of investments of $102 million but excludes extraordinary net gain on debt-for-equity exchange of $57 million ($0.30 per share). h Excludes net gain on sale of Wanda Petroleum Co. of $52 million ($0.28 per share). i Excludes net gain on sale of Canadian oil and gas properties of $50 million ($0.28 per share). j Excludes cumulative effects of change in accounting for investment tax credits of $320 million ($1.74 per share). k Excludes net gain on sale of property of $7.3 million ($0.19 per share). l Includes loss on divestitures of $1.9 million ($0.23 per share). m Fiscal year ends June 30. n From continuing operations; excludes net loss from discontinued FirstMiss subsidiary of $6.4 million ($0.30 per share). o Includes gain on restructuring Chemed Corp. of $65.1 million and net losses on disposal of businesses of $600,000. p Includes net gains on disposal of businesses of $31.1 million. q Includes net losses on disposal of businesses of $10.3 million. r Includes net gains on disposal of businesses of $5.2 million.

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
Hercules														
1982	$2,468,971	$ 86,661[a]	$2,001,354	2.2	$923,676	$164,997	$1,078,911	3.5%	8.1%	$1.97[a]	$1.32	5.8%	$28¾–16⅞	11.6
1981	2,718,366	136,481	1,997,144	2.5	907,733	167,189	1,051,357	5.0	13.0	3.09	1.26	5.6	26⅜–18¾	7.3
1980	2,485,226	114,000	1,869,679	2.0	872,656	229,163	1,009,746	4.6	11.3	2.60	1.20	6.0	25–15⅛	7.7
1979	2,345,425	144,500[b]	1,761,177	1.9	772,889	185,998	945,422	6.2	15.3	3.27[b]	1.075	5.5	22¾–16⅛	5.9
Philip A. Hunt Chemical Corp.														
1982	$114,849	$5,273	$87,953	2.6	$34,281	$4,104	$57,899	4.6%	9.1%	$0.93	$0.40	3.0%	$ 18–8⅝	14.3
1981	111,871	3,816[c]	87,238	2.6	36,231	9,105	56,005	3.4	6.6	0.67[c]	0.40	3.9	12⅛–8½	15.4
1980	106,296	4,044[d]	78,020	3.0	32,376	6,930	56,788	3.8	7.1	0.71[d]	0.40	3.5	14¼–8½	16.0
1979	106,004	8,015	72,794	3.4	29,067	9,206	55,606	7.6	14.4	1.41	0.40	2.9	17–11	9.9
International Flavors & Fragrances														
1982	$447,889	$63,160	$431,589	4.1	$135,565	$28,369	$335,902	14.1%	18.8%	$1.73	$1.01	4.3%	$ 30–17⅜	13.7
1981	451,088	66,123	430,990	3.8	125,97[illegible]	16,558	329,878	14.7	20.0	1.81	0.94	4.6	23–17⅞	11.3
1980	448,309	63,232	414,859	3.8	121,228	17,461	315,485	14.1	20.0	1.73	0.86	3.9	27½–16⅝	12.8
1979	409,299	61,472	387,807	3.6	114,2[illegible]5	15,180	285,425	15.0	21.5	1.68	0.74	3.4	25⅝–18¼	13.1
International Minerals & Chemical Corp.														
1982[e]	$1,560,400	$122,300[f]	$1,941,900	1.8	$1,941,900	$161,600	$1,010,200	7.8%	12.1%	$4.50[f]	$2.60	8.6%	$36⅞–23½	6.6
1981[e]	1,984,900	153,800	1,975,200	1.7	1,896,300	336,600	975,300	7.7	15.8	5.63	2.46	5.1	66½–30⅝	8.6
1980[e]	1,789,600	145,900	1,848,600	2.0	1,062,900	262,100	881,3[illegible]	8.2	16.6	5.38	2.16	4.5	66½–30	9.0
1979[e]	1,474,700	120,800	1,537,600	1.7	936,600	173,500	79[illegible]	8.2	15.3	4.48	1.87	5.8	41–23½	7.2
Liquid Air Corp.														
1982	$448,996	$27,512	$503,090	1.8	$353,376	$58,657	$247,801	6.1%	11.1%	$2.13	$1.60	9.1%	$20¾–14¾	8.3
1981	427,991	31,529[g]	465,128	1.6	285,026	61,818	239,776	7.4	13.1	2.86[g]	1.55	6.7	29¾–16¾	8.1
1980	408,249	27,448[h]	425,502	1.6	270,778	60,469	202,832	6.7	13.5	2.57[h]	1.40	5.2	34½–19¾	10.6
1979	369,109	24,698	399,354	1.7	250,006	50,714	191,641	6.7	12.9	2.49	1.40	5.3	2[illegible]¾–23¾	10.5
Lubrizol Corp.														
1982	$806,284	$ 47,561	$643,744	2.6	$288,504	$51,589	$462,044	5.9%	10.3%	$1.21	$1.08	5.7%	$23¾–14¼	15.7
1981	878,291	92,031	673,165	2.6	284,068	75,399	478,516	10.5	19.2	2.36	1.08	3.9	35½–20⅝	11.8
1980	902,312	111,511	651,137	2.5	248,664	92,140	452,787	12.4	24.6	2.87	0.90	2.7	41¾–24⅞	11.6
1979	724,734	90,775	519,942	2.5	180,405	50,807	374,751	12.5	24.2	2.33	0.80	3.2	30–20½	10.8
Monsanto Co.														
1982	$6,325,000	$329,000[i]	$6,077,000	2.4	$3,313,000	$673,000	$3,490,000	5.2%	9.4%	$8.21[i]	$3.95	5.4%	$ 89–56⅝	8.9
1981	6,947,700	445,100[j]	6,069,200	2.2	3,183,900	667,900	3,330,200	6.4	13.4	11.50[j]	3.75	5.1	87½–59½	6.4
1980	6,573,600	148,800[k]	5,796,400	1.9	3,109,100	780,500	2,808,200	2.3	5.3	4.10[k]	3.55	6.3	70¼–42¼	13.7
1979	6,192,600	331,000[l]	5,539,100	2.2	2,817,800	565,900	2,781,800	5.3	11.9	9.11[l]	3.35	6.3	62–45	5.9
Nalco Chemical Co.														
1982	$643,863	$64,356[m]	$464,868	2.2	$194,450	$56,241	$336,488	10.0%	19.1%	$1.62[m]	$1.12	4.3%	$ 34–18	16.0
1981	666,591	81,209	466,175	2.2	176,959	59,423	335,974	12.2	24.2	2.02	1.00	4.0	29⅛–20½	12.3
1980	616,799	72,261	416,233	2.7	138,137	34,923	306,550	11.7	23.6	1.80	0.80	3.9	26⅝–14	11.2
1979	578,908	63,277	368,074	2.5	126,774	30,018	261,966	10.9	24.2	1.59	0.68	4.4	17⅝–13⅛	9.7
Olin Corp.														
1982	$1,823,137	$62,800[n]	$1,636,027	1.7	$839,974	$139,015	$805,185	3.4%	7.8%	$2.68[n]	$1.20	5.7%	$26¼–15½	7.8
1981	2,001,346	92,836	1,618,034	1.6	844,927	186,331	793,187	4.6	11.7	3.88	1.15	4.9	27–19½	6.0
1980	1,852,853	73,931[o]	1,550,128	1.7	822,412	172,016	750,120	4.0	9.9	3.08[o]	1.025	5.8	23⅛–12½	5.8
1979	1,778,102	71,150	1,461,073	1.7	764,108	161,151	739,992	4.0	9.6	2.97	0.97	4.7	25–16⅛	6.9
Pennwalt Corp.														
1982	$ 952,400	$24,502[p]	$737,048	1.6	$342,785	$76,466	$346,364	2.6%	7.1%	$2.37[p]	$2.20	7.8%	$34⅞–21½	11.9
1981	1,056,118	36,661[q]	755,755	2.1	309,525	52,696	367,098	3.5	10.0	3.55[q]	2.20	7.1	36–26¼	8.8
1980	1,188,702	43,291	810,761	2.0	314,315	55,546	373,363	3.6	11.6	4.20	2.20	7.4	34⅜–25⅜	7.1
1979	1,079,303	49,997	775,355	2.1	298,420	67,486	346,140	4.6	14.4	5.01	2.20	6.1	35⅞–30½	6.6
Reichhold Chemicals														
1982	$814,911	$ 6,875[r]	$364,133	2.5	$159,181	$20,516	$200,546	0.8%	3.4%	$0.57[r]	$0.48	3.2%	$19⅝–10	26.0
1981	950,112	17,054[s]	405,477	2.3	173,398	15,908	206,727	1.8	8.2	2.04[s]	0.48	3.5	16–11⅛	6.6
1980	885,059	16,114	424,760	2.1	179,550	22,656	203,941	1.8	7.9	1.90	0.61	5.0	15–9⅝	6.5
1979	874,854	12,239	425,478	2.0	179,960	26,114	194,619	1.4	6.3	1.34	0.74	5.4	16–11¼	10.2
Rohm & Haas Co.														
1982	$1,828,027	$85,605[t]	$1,365,163	2.5	$546,623	$125,927	$807,853	4.7%	10.6%	$6.63[t]	$2.80	4.5%	$79⅛–45½	9.4
1981	1,884,664	93,385[u]	1,348,627	2.4	537,489	181,635	759,911	4.9	12.2	7.21[u]	2.56	4.3	71¾–46¾	8.2
1980	1,725,304	93,744	1,240,456	2.6	488,185	93,013	703,124	5.4	13.3	7.26	2.16	4.9	55¼–32¾	6.1
1979	1,590,484	95,495[v]	1,191,903	2.3	487,841	68,328	637,398	6.0	15.0	7.39[v]	1.76	4.4	48½–31½	5.4

a Excludes extraordinary net gain on debt-for-equity exchange of $11.6 million ($0.25 per share). b Excludes net gain on sale of pigments and methanol assets of $28.0 million ($0.62 per share). c From continuing operations; excludes net loss on disposal of photofinishing business of $146,000 ($0.03 per share). d From continuing operations; excludes net loss on operations and disposal of photofinishing business of $1.9 million ($0.33 per share). e Fiscal year ends June 30. f From continuing operations; excludes earnings and net gain on disposal of discontinued chemical operations of $15.1 million ($0.57 per share). g Includes net gain on sale of assets, before taxes, of $1.0 million. h Excludes net gain on sale of assets of $2.0 million ($0.19 per share). i Excludes extraordinary net gain on debt-for-equity exchange of $23 million ($0.58 per share) but includes net loss on sale of European acrylic fibers business of $18 million ($0.46 per share). j Includes net gain on sale of joint venture of $67.7 million ($1.75 per share). k Includes net loss on withdrawal from polyester filament business in the U.S. of $69.0 million ($1.90 per share) and from termination of Aiscondel of $38.7 million ($1.07 per share). l Includes nonrecurring net charges for shutdown of European businesses of $53.2 million ($1.47 per share). m Excludes net loss on discontinued Industrial Bio-Test Laboratories operations of $6.2 million ($0.16 per share). n Excludes special charge for DDT claims, net, of $9.5 million ($0.40 per share). o Excludes net charge for restructuring of Winchester group of $40.0 million ($1.07 per share). p From continuing operations; excludes provision for loss on disposal of discontinued operations of $2.8 million ($0.27 per share). q From continuing operations; includes cost of shutdown of chlorine-caustic plant, before taxes, of $21.5 million but excludes net loss on operations and disposal of discontinued businesses of $11.4 million ($1.10 per share) and nonrecurring net gain from cumulative effect of change in accounting for investment credit of $16.3 million ($1.57 per share). r Excludes net loss resulting from asset redeployment/divestiture program of $2.2 million ($0.32 per share). s Excludes extraordinary net charge for settlement of litigation of $2.4 million ($0.34 per share). t Includes net gain on shutdown and disposal of assets of $10.4 million ($0.80 per share). u Includes net loss from shutdown and disposal of assets of $6.6 million ($0.50 per share). v Excludes extraordinary tax credit of $7.3 million ($0.57 per share).

Finances of the U.S. Chemical Industry 2

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Stauffer Chemical Co.														
1982	$1,618,235	$123,547	$2,170,162	2.5	$1,200,576	$176,872	$1,065,751	7.6%	11.6%	$2.81	$1.41	6.2%	$\$28\frac{3}{8}-17$	8.1
1981	1,726,236	150,093[a]	2,013,863	2.4	1,170,253	238,555	1,009,034	8.7	14.9	3.41[a]	1.29	5.5	$27\frac{3}{4}-18\frac{3}{8}$	6.8
1980	1,695,219	121,743[b]	2,084,441	1.4	1,072,896	246,454	909,490	7.2	13.4	2.77[b]	1.175	6.0	$24\frac{3}{8}-14\frac{1}{2}$	7.0
1979	1,526,160	135,961	1,846,866	1.7	1,040,542	239,303	821,777	8.9	16.5	3.10	1.075	5.0	$25-17\frac{3}{4}$	6.9
Stepan Chemical Co.														
1982	$208,373	$5,303	$163,326	1.3	$75,475	$16,148	$55,067	2.5%	9.6%	$1.45	$0.56	4.1%	$\$18\frac{1}{8}-9\frac{1}{4}$	9.4
1981	204,522	6,545[c]	176,068	1.5	67,906	12,083	53,888	3.2	12.1	1.74	0.515	3.0	$21\frac{7}{8}-12\frac{3}{8}$	9.8
1980	157,517	3,683[d]	137,686	1.5	64,338	9,204	50,498	2.3	7.3	0.98[d]	0.47	4.5	$12\frac{1}{4}-8\frac{1}{2}$	10.5
1979	144,981	4,794[e]	112,700	2.3	66,121	13,575	46,399	3.3	10.3	1.28[e]	0.415	4.2	$11\frac{3}{4}-8\frac{1}{4}$	7.8
Union Carbide Corp.														
1982	$ 9,061,000	$310,000	$10,552,000	1.9	$6,356,000	$1,179,000	$5,095,000	3.4%	6.1%	$ 4.47	$3.40	6.7%	$\$\ 61-40\frac{7}{8}$	11.3
1981	10,168,000	649,000	10,366,000	2.1	5,794,000	1,186,000	5,206,000	6.4	12.5	9.56	3.30	6.1	$62\frac{1}{8}-45\frac{1}{4}$	5.6
1980	9,994,000	673,000[f]	9,600,000	2.1	5,207,000	1,129,000	4,717,000	6.7	14.3	10.08[f]	3.10	7.1	$52\frac{1}{2}-35\frac{1}{4}$	4.4
1979	9,176,500	556,200[g]	8,710,000	2.1	4,458,300	831,300	3,949,900	6.1	14.1	8.47[g]	2.90	7.4	$44\frac{1}{2}-34$	4.6
Williams Cos.														
1982	$1,691,315	$ 29,682[h]	$2,369,791	1.7	$1,513,712	$171,895	$1,029,411	1.8%	2.9%	$1.00[h]	$1.20	5.6%	$\$29\frac{3}{8}-13\frac{1}{8}$	21.2
1981	1,976,336	99,167[i]	2,445,877	1.6	1,497,797	233,184	1,027,245	5.0	9.7	3.32[i]	1.20	3.4	$46\frac{5}{8}-23\frac{1}{2}$	10.6
1980	2,072,686	138,696	2,380,001	1.8	1,417,799	339,625	965,715	6.7	14.4	5.07	1.10	2.9	$49\frac{3}{8}-26\frac{3}{4}$	7.5
1979	1,850,013	69,450	2,005,511	1.7	1,190,526	112,995	737,949	3.8	9.4	2.55	1.00	4.2	$32\frac{1}{4}-15$	9.3
Witco Chemical Corp.														
1982	$1,305,418	$29,842	$643,911	2.2	$291,914	$54,130	$281,013	2.3%	10.6%	$3.15	$1.80	7.2%	$\$29\frac{1}{2}-20\frac{5}{8}$	8.0
1981	1,291,876	38,580	707,181	1.7	281,945	55,479	277,973	3.0	13.9	4.14	1.65	6.1	$31\frac{1}{2}-22\frac{3}{4}$	6.6
1980	1,175,695	40,954	612,882	2.1	238,761	45,663	248,315	3.5	16.5	4.50	1.50	5.6	$33\frac{3}{4}-20\frac{1}{4}$	6.0
1979	966,758	42,782	551,891	1.9	192,902	40,890	222,686	4.4	19.2	4.83	1.30	5.1	$30\frac{1}{2}-20$	5.2
PHARMACEUTICALS														
Abbott Laboratories														
1982	$2,602,447	$289,123	$2,566,909	1.1	$901,059	$223,900	$1,310,886	11.1%	22.1%	$2.37	$0.84	2.5%	$\$41\frac{1}{4}-25\frac{3}{8}$	14.1
1981	2,342,524	247,283	2,355,613	1.1	729,402	200,600	1,152,050	10.6	21.5	2.01	0.72	2.6	$32\frac{1}{4}-23\frac{5}{8}$	13.9
1980	2,038,156	214,413	2,062,835	1.2	583,214	162,548	1,027,222	10.5	20.9	1.73	0.60	2.6	$28\frac{1}{2}-17$	13.2
1979	1,683,168	178,981[j]	1,729,296	1.3	466,970	109,636	896,028	10.6	20.0	1.48[j]	0.50	2.7	$21\frac{3}{4}-14\frac{3}{4}$	12.3
American Home Products Corp.														
1982	$4,582,096	$560,103	$2,602,346	2.6	$725,352	$153,812	$1,614,192	12.2%	34.7%	$3.59	$2.15	5.3%	$\$\ 48-33\frac{1}{4}$	11.3
1981	4,131,237	497,332	2,517,541	3.0	492,879	99,852	1,583,475	12.0	31.4	3.18	1.90	5.8	$37\frac{1}{4}-28\frac{1}{8}$	10.3
1980	3,798,524	445,889	2,289,460	2.8	450,490	99,393	1,391,972	11.7	32.0	2.84	1.70	6.4	$31\frac{7}{8}-21\frac{3}{8}$	9.4
1979	3,401,301	396,039	2,007,977	3.0	408,899	87,809	1,239,315	11.6	32.0	2.51	1.50	5.6	$29\frac{1}{2}-24\frac{3}{8}$	10.7
Baxter Travenol Laboratories														
1982	$1,671,445	$186,885	$1,792,710	1.9	$628,720	$148,812	$1,061,009	11.2%	17.6%	$2.64	$0.46	1.1%	$\$\ 51-30\frac{5}{8}$	15.4
1981	1,503,890	150,581	1,590,743	2.6	583,084	87,101	978,325	10.0	15.4	2.15	0.38	1.3	$33\frac{3}{4}-24$	13.4
1980	1,374,384	128,400	1,412,638	2.8	560,690	118,645	852,606	9.3	15.1	1.86	0.32	1.4	$28\frac{3}{8}-17\frac{7}{8}$	12.4
1979	1,191,193	111,908[k]	1,290,928	2.3	500,976	103,654	723,510	9.4	15.5	1.14[k]	0.25	1.2	$24\frac{3}{4}-17\frac{3}{4}$	12.9
Bristol-Myers Co.														
1982	$3,599,900	$348,700	$2,665,800	2.2	$653,600	$170,000	$1,624,000	9.7%	21.5%	$5.18	$2.035	3.3%	$\$\ 74-50\frac{3}{4}$	12.0
1981	3,496,700	305,800	2,406,000	2.2	581,800	159,300	1,482,000	8.7	20.6	4.58	1.78	3.4	$58\frac{3}{4}-45\frac{3}{4}$	11.4
1980	3,158,300	270,600	2,125,500	2.3	484,900	131,600	1,296,200	8.6	20.9	4.08	1.56	3.8	$52-30\frac{1}{2}$	10.1
1979	2,752,777	231,545	1,837,648	2.4	407,528	95,022	1,117,002	8.4	20.7	3.50	1.385	4.0	$38\frac{1}{4}-31$	9.9
Eli Lilly & Co.														
1982	$2,962,711	$411,828	$3,155,125	1.8	$1,135,575	$236,642	$2,055,460	13.9%	20.0%	$5.42	$2.60	4.7%	$\$65\frac{1}{4}-45\frac{1}{2}$	10.2
1981	2,773,205	374,478	2,902,262	1.9	1,006,180	253,735	1,888,260	13.5	19.8	4.93	2.375	4.2	$68\frac{3}{4}-45\frac{1}{4}$	11.6
1980	2,558,637	341,974	2,607,452	2.0	849,034	230,700	1,736,693	13.4	19.7	4.52	2.20	4.0	$65\frac{1}{2}-45\frac{3}{4}$	12.3
1979	2,205,764	329,531	2,179,132	2.4	672,610	172,678	1,570,439	14.9	21.0	4.52	1.95	3.5	$63\frac{7}{8}-47\frac{1}{8}$	12.3
Merck & Co.														
1982	$3,063,017	$415,137	$3,647,652	1.9	$1,557,490	$295,106	$2,203,988	13.6%	18.8%	$5.61	$2.80	3.7%	$\$88\frac{1}{4}-64$	13.6
1981	2,929,455	398,265	3,310,000	1.7	1,395,567	322,814	2,001,460	13.6	19.9	5.36	2.60	2.9	$103-76\frac{1}{4}$	15.7
1980	2,734,012	415,396	2,865,755	2.3	1,185,244	256,488	1,863,322	15.2	22.3	5.54	2.30	3.2	$86-58\frac{1}{4}$	13.0
1979	2,384,627	381,776	2,614,064	2.2	1,027,644	170,134	1,665,496	16.0	22.9	5.06	1.90	2.8	$74\frac{1}{4}-62\frac{1}{2}$	13.5

[a] Excludes net loss on facility disposal and asset write-down of $169,000. [b] Excludes net gain on disposal of facilities of $14.8 million ($0.34 per share). [c] Includes loss on sale of flavor compounding business, before taxes, of $890,000. [d] Excludes net gain on sale of Polychem department of $1.7 million ($0.95 per share). [e] Excludes net gain on sale of fragrance business of $528,000 ($0.28 per share). [f] Excludes cumulative effect of change in accounting principle for investment tax credit of $217 million ($3.28 per share). [g] Includes net charge on sales and disposals of assets of $21.1 million. [h] From continuing operations; excludes net income from discontinued operations of $4.7 million ($0.15 per share). [i] From continuing operations; excludes net income from discontinued operations of $10.4 million ($0.35 per share). [j] Includes net gain on sale of animal health business of $1.8 million ($0.02 per share). [k] Includes net gain on sale of assets of $450,000.

2 Finances of the U.S. Chemical Industry

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
Pfizer														
1982	$3,453,600	$332,800	$3,644,500	1.9	$1,124,700	$265,500	$1,869,500	9.6%	17.8%	$4.26	$1.84	2.9%	$80⅝–49⅞	15.3
1981	3,249,700	273,700[a]	3,544,200	1.9	998,200	287,100	1,594,700	8.4	17.2	3.63[a]	1.60	3.4	54⅞–40	13.1
1980	3,029,300	254,800	3,247,300	1.9	825,000	163,600	1,456,500	8.4	17.5	3.48	1.44	3.4	53¾–32	12.3
1979	2,746,025	237,869	2,945,280	2.0	759,269	133,300	1,310,074	8.7	18.2	3.26	1.32	3.7	41¾–29	10.9
Richardson-Vicks														
1982[b]	$1,115,600	$66,900	$687,100	2.0	$247,000	$57,500	$394,600	6.0%	17.0%	$2.74	$1.48	5.6%	$32½–20½	9.7
1981[b]	1,088,100	83,200[c]	672,200	1.7	208,600	49,300	365,300	7.3	22.8	3.47[c]	1.32	4.7	34¾–21¾	8.1
1980[b,d]	1,211,651	84,209	829,551	2.0	242,568	52,630	427,938	6.9	19.7	3.56	1.20	4.3	38⅛–17½	7.8
1979[b,d]	1,090,546	62,956	718,229	2.1	209,251	47,545	376,852	5.8	16.7	2.66	1.06	4.5	27–19¾	8.8
A. H. Robins Co.														
1982	$482,324	$48,693[e]	$306,043	3.8	$98,079	$15,815	$267,945	10.1%	18.2%	$1.98[e]	$0.52	3.3%	$20⅛–11¼	7.9
1981	450,854	44,228[f]	385,483	3.0	95,457	28,103	251,742	9.8	17.6	1.77[f]	0.44	3.8	14¾–8½	6.6
1980	432,328	25,470[g]	337,318	2.9	80,511	30,273	227,142	5.9	11.2	1.01[g]	0.42	4.4	12½–5⅝	9.5
1979	386,425	44,746[h]	329,072	2.8	59,994	16,687	222,148	11.6	20.1	1.71[h]	0.40	4.0	12–8¼	5.9
Schering-Plough Corp.														
1982	$1,817,900	$183,500	$2,341,100	1.8	$747,500	$180,400	$1,278,500	10.1%	14.4%	$3.39	$1.68	4.8%	$43¾–26¼	10.3
1981	1,808,800	179,300	2,214,500	1.9	654,600	170,300	1,254,200	9.9	14.3	3.31	1.66	4.9	42½–24⅞	10.2
1980	1,740,400	239,300	1,925,800	1.7	524,800	130,900	1,193,800	13.7	20.0	4.45	1.56	4.2	45⅝–29⅛	8.4
1979	1,434,022	222,267	1,534,245	2.0	415,401	68,316	1,037,354	15.5	21.4	4.12	1.39	4.4	35¼–27½	7.6
G. D. Searle & Co.														
1982	$1,036,900	$140,400	$1,204,500	2.1	$377,800	$135,200	$599,700	13.5%	23.4%	$2.77	$0.52	1.4%	$45¼–28⅝	13.3
1981	942,300	130,900[j]	1,050,400	2.3	279,300	87,600	533,600	13.9	24.5	2.52[j]	0.52	1.7	35½–25⅛	12.0
1980	1,081,558	94,341[i]	1,089,920	1.4	249,695	66,961	508,844	8.7	18.5	1.70[i]	0.52	2.3	27⅝–17¼	12.6
1979	898,369	89,004[k]	1,099,383	1.9	212,972	49,253	456,358	9.9	19.5	1.60[k]	0.52	3.3	20–11½	9.4
SmithKline Beckman Corp.														
1982	$2,968,667	$455,157	$2,765,900	2.1	$971,302	$304,784	$1,749,407	15.3%	26.0%	$5.51	$2.39	3.5%	$77⅝–57⅜	12.3
1981	1,985,341	370,000	1,796,105	2.3	580,920	200,816	1,139,457	18.6	32.5	5.55	2.12	2.8	88⅜–[illegible]	13.7
1980	1,771,938	307,994	1,490,914	2.4	421,788	132,806	923,723	17.4	33.3	4.65	1.725	2.8	80⅝–43½	13.3
1979	1,351,145	[illegible]	1,150,260	2.3	289,847	93,494	667,468	17.3	35.0	3.85	1.32	2.6	63⅛–38½	13.2
Squibb Corp.														
1982	$1,660,766	$153,636	$1,871,882	2.1	$511,821	$ 87,280	$1,037,989	9.3%	14.8%	$3.01	$1.28	3.2%	$50½–29	13.2
1981	1,523,911	41,098[l]	1,900,424	2.1	479,720	69,851	979,689	2.7	4.2	0.83[l]	1.215	3.8	37⅝–26⅝	38.7
1980	1,675,780	123,079[m]	1,858,270	2.3	600,895	89,032	964,504	7.3	12.8	2.50[m]	1.155	3.6	39¼–24⅝	12.4
1979	1,782,894	123,722	1,747,688	2.2	630,047	109,970	881,875	6.9	14.0	2.71	1.095	3.3	39¼–27	12.2
Sterling Drug														
1982	$1,796,153	$131,970	$1,297,989	2.6	$356,535	$80,068	$825,944	7.3%	16.0%	$2.17	$1.06	4.3%	$29⅝–19¾	11.4
1981	1,792,925	130,303	1,226,410	2.5	334,980	77,016	787,542	7.3	16.5	2.15	0.98	4.3	26⅛–19	10.5
1980	1,701,433	123,337	1,214,231	2.4	318,109	70,051	752,640	7.2	16.4	2.04	0.90	4.2	26⅞–16	10.5
1979	1,500,692	111,594	1,105,581	2.3	280,594	58,186	680,649	7.4	16.4	1.85	0.82	4.5	21⅜–15¼	9.9
Upjohn Co.														
1982	$1,828,730	$126,020	$2,013,985	1.9	$675,869	$137,273	$973,028	6.9%	13.0%	$4.18	$2.28	4.7%	$59⅜–38	11.6
1981	1,898,334	181,764	1,940,485	2.0	614,481	139,211	965,267	9.6	18.8	6.04	2.07	3.6	69–45⅝	9.5
1980	1,760,576	170,375	1,669,621	1.9	544,322	109,800	865,753	9.7	19.7	5.71	1.93	3.5	68–41½	9.6
1979	1,508,025	149,478	1,403,734	2.1	476,357	77,498	743,659	9.9	20.1	5.03	1.62	3.6	50½–40	9.0
Warner-Lambert Co.														
1982	$3,245,967	$174,970[n]	$2,344,259	1.9	$768,571	$153,507	$ 815,864	5.4%	21.4%	$2.20[n]	$1.40	5.6%	$30⅛–19⅝	11.3
1981	3,379,952	9,222[o]	2,662,418	1.7	869,753	165,833	1,084,796	0.3	0.9	0.12[o]	1.34	6.4	25–17⅛	175.5
1980	3,479,207	192,716[p]	2,638,077	2.1	827,131	138,688	1,171,477	5.5	16.5	2.41[p]	1.32	6.6	23¼–17	8.4
1979	3,217,208	123,346[q]	2,542,167	1.9	775,253	155,473	1,067,151	3.8	11.6	1.55[q]	1.29	5.8	26½–17⅜	14.3

a From continuing operations; excludes net loss from discontinued diagnostic imaging operations and provision for loss on disposal of discontinued operations of $52.4 million ($0.68 per share). b Fiscal year ends June 30. c From continuing operations; excludes net loss from discontinued ethical pharmaceutical businesses of $3.9 million ($0.16 per share). d Data for Richardson-Merrell prior to sale (in March 1981) of ethical pharmaceutical businesses to Dow Chemical Co. e Includes income, before taxes, from litigation settlement of $3.1 million. f Includes income, before taxes, from litigation settlement of $3.4 million. g Includes income, before taxes, from litigation settlement of $3.6 million and provision for net losses on disposition of businesses of $4.7 million ($0.19 per share). h Includes income, before taxes, from settlement of antitrust litigation of $28.9 million. i From continuing operations; excludes net loss from operations and disposition of discontinued businesses of $26.0 million ($0.50 per share) and debit for cumulative effect of changes in accounting principles of $6.2 million ($0.12 per share). j From continuing operations; excludes reserve for loss from sale of assets of diagnostic business of $9.0 million ($0.17 per share) and extraordinary tax credit of $13.0 million ($0.24 per share). k From continuing operations; excludes net loss from operations of divested diagnostic business of $1.1 million ($0.02 per share). l From continuing operations; excludes net gain on sale of confectionery products business of $58.1 million ($1.16 per share), net income from that business of $12.2 million ($0.24 per share), and extraordinary charge relating to takeover of operations in Iran of $6.5 million ($0.13 per share). m From continuing operations; excludes net income of divested food services and related operations of $4.3 million ($0.09 per share). n Includes nonrecurring net credit of $12 million ($0.15 per share). o Includes nonrecurring net charge of $134 million ($1.68 per share). p Includes nonrecurring net charge of $3 million ($0.03 per share). q Includes nonrecurring net charges and tax settlement of $64 million ($0.80 per share).

Productivity drops as capacity use stays low

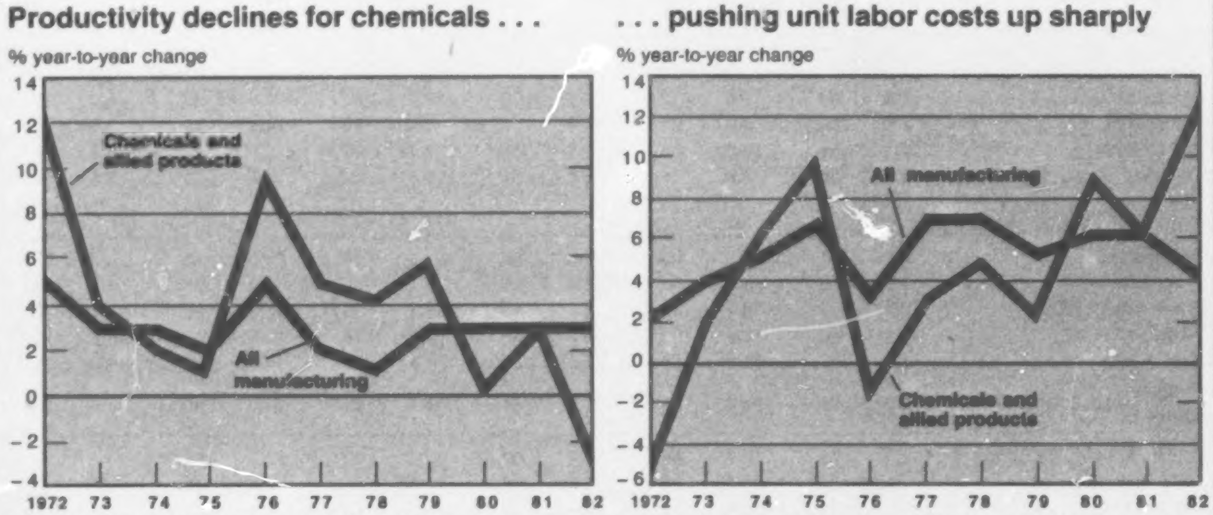
Some of the most common measures of industrial efficiency look pretty bad for 1982. The sharp drop in the U.S. economy last year and the resulting drop in chemical output and plant use rates skewed everything.

The odd result is that the chemical industry reversed its usual position, relative to manufacturing as a whole, in its labor productivity and unit labor costs. It was not quite so brutal as all manufacturing in slashing worktime and curbing wage gains in the face of the recessionary decline in production.

Production fell 9% in 1982 for the chemical industry and 8% for all manufacturing. But chemical companies cut total workhours per week just 6%, whereas all manufacturing sliced worktime 11%. And chemical companies still increased the wages of production people 9% in 1982, but all manufacturing gave only a 6% gain.

So productivity (output per workhour in production units) in chemical plants fell 3% in 1982—the first drop in at least 20 years—and unit labor costs (costs per unit of output) soared 13%. For all manufacturing, productivity gained 3% and unit labor costs did also.

Chemical plant use stayed very low all last year and is still low. For a sample of basic chemicals, C&EN semiannual surveys show that the combined use rate early in 1982 was just 60% of the nameplate maximum and climbed only to 63% early in 1983.



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Department of Labor, Federal Reserve Board, C&EN calculations

PRODUCTIVITY: For chemical firms, a slump last year after the previous year's modest gain

Indexes, 1967 = 100	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
CHEMICALS & ALLIED PRODUCTS											
Production	196.1	215.6	207.1	211.8	197.4	185.7	170.9	147.2	159.4	154.4	143.6
Workhours	99.3	106.1	105.4	107.7	106.8	104.5	101.4	96.5	105.1	103.7	100.3
Productivity	197.5	203.2	196.5	196.7	184.8	177.7	168.5	152.5	151.7	148.9	143.2
Hourly production wages	321.9	294.2	267.7	245.2	226.5	207.4	190.7	173.9	157.4	145.5	137.4
Unit labor costs	163.0	144.3	136.2	124.7	122.6	116.7	113.2	114.0	103.8	97.7	95.9
ALL MANUFACTURING											
Production	138.6	150.4	146.7	153.6	146.8	138.4	130.3	116.3	129.4	129.8	118.9
Workhours	84.9	95.3	96.2	103.3	101.7	97.3	93.4	87.8	100.0	103.1	97.3
Productivity	163.3	157.8	152.5	148.7	144.3	142.2	139.5	132.5	129.2	125.9	122.2
Hourly production wages	300.4	282.3	256.9	236.7	218.0	200.7	185.1	171.3	156.7	145.0	135.5
Unit labor costs	184.0	178.9	168.5	159.2	151.1	141.1	132.7	129.3	121.1	115.2	110.9

Sources: Department of Labor, Federal Reserve Board, C&EN calculations

3 Efficiency in the U.S. Chemical Industry

OPERATING RATES: Use of chemical plant capacity remains very low

Billions of lb per year unless otherwise noted[a]	1ST-QTR 1983		3RD-QTR 1982		1ST-QTR 1982		3RD-QTR 1981		1ST-QTR 1981		3RD-QTR 1980	
	Capacity[b]	Use	Capacity[b]	Use	Capacity[b]	Use	Capacity[b]	Use	Capacity[b]	Use	Capacity[b]	Use
ORGANIC CHEMICALS												
Benzene (bg)	2.3	43%	2.4	48%	2.4	44%	2.7	67%	2.5	68%	2.4	64%
Butadiene[c]	4.5	37	4.4	40	4.6	42	4.6	67	4.6	61	4.0	65
Cyclohexane	3.4	31	3.1	37	3.1	33	3.4	59	3.4	62	3.4	52
DMT-TPA[d]	7.3	64	7.3	56	7.3	58	7.3	71	7.3	71	7.3	59
Ethylene	39.0	67	39.0	61	39.7	56	41.0	65	40.0	68	40.0	63
Formaldehyde, 37% solution	9.2	55	8.9	47	8.9	51	8.9	65	8.9	66	8.6	59
Methanol (bg)	1.7	56	1.6	76	1.5	72	1.4	83	1.4	90	1.4	80
Phenol	3.6	64	3.6	61	4.0	56	4.0	67	3.6	69	3.7	65
Propylene, chemical	23.0	49	23.0	56	23.0	44	23.5	59	23.5	58	23.8	48
Styrene	8.2	64	8.7	69	8.7	79	8.9	74	8.9	82	8.9	55
Urea	7.8	73	7.8	72	7.8	65	8.0	90	8.0	88	8.0	91
Vinyl acetate	2.4	90	2.3	91	2.4	72	2.4	79	2.5	78	2.5	68
Vinyl chloride	10.1	65	10.0	68	9.6	50	9.7	70	9.2	65	8.2	63
***p*-Xylene**	4.9	68	4.9	60	5.5	54	5.6	64	5.6	75	5.6	68
INORGANIC CHEMICALS												
Ammonia (mt)	18.7	71	19.8	82	19.8	84	24.0	80	24.0	83	24.0	75
Carbon black	3.3	63	3.4	62	3.4	75	3.4	82	3.7	76	3.7	61
Carbon dioxide (ttd)	18.9	61	18.4	67	17.7	63	16.4	71	15.6	69	15.6	68
Caustic soda (mt)	15.4	66	15.6	61	15.7	59	15.5	75	15.6	73	15.3	68
Chlorine (mt)	14.4	66	14.6	64	14.8	[illegible]	14.8	78	14.7	73	14.6	69
Nitrogen **Oxygen** } total, liquid (ttd)	37.0	64	36.6	65	37.6	64	36.0	66	34.8	63	33.6	69
Phosphoric acid, (P_2O_5) (mt)	12.5	71	12.6	64	12.4	62	11.5	91	11.7	94	11.7	87
Phosphorus (mt)	0.55	82	0.55	68	0.55	66	0.55	78	0.55	78	0.55	70
Soda ash (mt)	10.7	74	10.9	73	10.4	76	10.0	83	10.0	82	9.7	79
Sulfuric acid (mt)	57.5	59	59.6	49	59.4	54	58.5	74	58.3	74	58.0	76
Titanium dioxide (mt)	1.0	60	1.0	61	1.0	53	1.0	82	1.0	77	1.0	66
AVERAGE		**63%**		**62%**		**60%**		**74%**		**74%**		**69%**

a bg = billions of gallons, mt = millions of tons, ttd = thousands of tons per day. b Nameplate capacity. c Total extraction capacity, which runs about 25% more than basic production capacity. d Dimethyl terephthalate-purified terephthalic acid, not including acid converted to dimethyl terephthalate. **Sources:** Industry sources, C&EN estimates

Excess capacity increased in the chemical process industries last year

	Operating rate, % of nameplate capacity, as of December										
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Chemicals	66%	70%	78%	83%	83%	76%	78%	78%	81%	88%	85%
Paper	79	83	89	91	89	87	85	85	84	93	91
Petroleum	69	73	80	86	91	91	93	91	90	95	94
Rubber	73	66	70	70	84	81	85	81	77	84	89
Textiles	74	75	80	82	85	87	84	85	69	89	91
All manufacturing	68	72	78	81	84	82	81	79	78	85	85

Source: Department of Commerce

ENERGY USE BY CHEMICAL INDUSTRY: Electricity and coal have been increasing their share

	1982		1981		1980		1979		1972		Change 1972–82	
Energy source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	1039	39.0%	1272	40.2%	1293	39.7%	1371	38.6%	1636	48.4%	−597	−36.5%
Purchased electricity[b]	790	29.7	931	29.4	943	29.0	998	28.1	718	21.3	72	10.0
Petroleum-based fuels	458	17.2	542	17.1	621	19.1	762	21.5	578	17.1	−120	−20.8
Light hydrocarbons[c]	321	12.1	351	11.1	380	11.7	433	12.2	322	9.5	−1	−0.3
Residual fuels	80	3.0	104	3.3	141	4.3	217	6.1	162	4.8	−82	−50.6
Distillate fuels	13	0.5	18	0.6	23	0.7	37	1.0	33	1.0	−20	−60.6
Other fuel[d]	44	1.6	70	2.2	77	2.4	75	2.1	61	1.8	−17	−27.9
Coal and coke	293	11.0	324	10.2	301	9.3	305	8.6	320	9.5	−27	−8.4
Purchased steam	82	3.1	98	3.1	95	2.9	115	3.2	123	3.7	−41	−33.3
TOTAL	2661	100.0%	3167	100.0%	3255	100.0%	3550	100.0%	3376	100.0%	−715	−21.2%

a For energy and process use only, excluding energy equivalent of feedstock. b Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. c Includes propane, liquefied petroleum gas, and other gases. d Includes petroleum coke, gasoline, and other liquids and solids. **Note:** Data from companies accounting for about 90% of U.S. capacity for basic industrial chemicals. **Source:** Chemical Manufacturers Association

ENERGY USE BY FERTILIZER INDUSTRY: Natural gas provides more than three quarters

	1982		1981		1980		1979[b]		1972		Change 1972–82	
Energy source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	151.8	76.8%	200.6	81.2%	205.0	79.3%	206.1	77.9%	161.3	79.3%	−9.5	−5.9%
Purchased electricity[c]	33.7	17.1	43.7	17.7	46.9	18.2	49.2	18.6	35.3	17.4	−1.6	−4.5
Petroleum-based fuels	4.4	2.3	1.8	0.7	5.8	2.2	8.6	3.3	6.2	3.1	−1.8	−29.0
Residual fuels	4.4	2.2	1.0	0.4	4.5	1.7	5.4	2.0	3.8	1.9	0.6	15.8
Distillate fuels	na	na	0.7	0.3	0.7	0.3	2.7	1.0	2.2	1.1	na	na
Other fuel[d]	0	0	0.2	0.1	0.6	0.2	0.6	0.2	0.2	0.1	0.2	−100
Coal and coke	na	na	0.5	0.2	0.6	0.2	0.5	0.2	0.5	0.2	na	na
Generated steam[e]	7.6	3.8	na	na	na	na	na	na	na	na	na	na
Purchased steam	0	0	0.4	0.1	0.2	0.1	0.2	0.1	0.1	0	−0.1	100
TOTAL	197.6	100.0%	246.9	99.9%	258.5	100.0%	264.6	100.1%	203.3	100.0%	−5.7	−2.8%

a For energy and process use only, excluding energy equivalent of feedstock. b Figures for 1979 include 18 companies (with total energy consumption of 209 trillion Btu) that use 1972 as a reference base and four companies (with total energy consumption of 56 trillion Btu) that use 1978 as a reference base instead; 1979 figures thus are not completely comparable to other years. c Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. d Includes propane, liquefied petroleum gas, gasoline, diesel oil, kerosene, and other fuels. e Steam generated from fossil fuel, listed prior to 1982 under residual fuels, distillate fuels, other fuel, and coal and coke. na = not available. **Note:** Data from companies accounting for more than 70% of U.S. fertilizer capacity. **Source:** Fertilizer Institute

ENERGY USE BY PETROLEUM INDUSTRY: Share provided by natural gas is shrinking

	1982		1981		1980		1979		1972		Change 1972–81	
Energy source[a]	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	% of total	Trillion Btu	%
Natural gas	591	22.4%	686	24.7%	734	25.1%	758	25.0%	995	33.5%	−404	−40.6%
Purchased electricity[b]	242	9.1	250	9.0	253	8.6	242	8.0	194	6.5	48	24.7
Petroleum-based fuels	1781	67.5	1810	65.1	1903	65.1	1989	65.7	1745	58.7	36	2.1
Light hydrocarbons[c]	1189	45.0	1194	43.0	1243	42.5	1291	42.7	1041	35.0	148	14.2
Residual fuels	149	5.6	177	6.4	215	7.3	234	7.7	246	8.3	−97	−39.4
Petroleum coke	429	16.2	428	15.4	425	14.5	431	14.3	432	14.5	−3	−0.7
Other fuel[d]	15	0.5	11	0.4	19	0.7	33	1.1	26	0.9	−11	−42.3
Coal and coke	6	0.2	5	0.2	4	0.1	5	0.2	5	0.2	1	20.0
Purchased steam	20	0.8	28	1.0	31	1.1	32	1.1	34	1.1	−14	−41.2
TOTAL	2640	100.0%	2779	100.0%	2925	100.0%	3026	100.0%	2973	100.0%	−333	−11.2

a For energy and process use only, excluding energy equivalent of feedstock. b Electricity is calculated as fuel value of 10,000 Btu to generate 1 kWh instead of using standard conversion factor of 3412 Btu per kWh. c Includes propane, liquefied petroleum gas, and refinery gas. d Includes distillate fuels, gasoline, and other liquids. **Note:** Data from companies accounting for about 90% of U.S. petroleum refining capacity, including Puerto Rico. **Source:** American Petroleum Institute

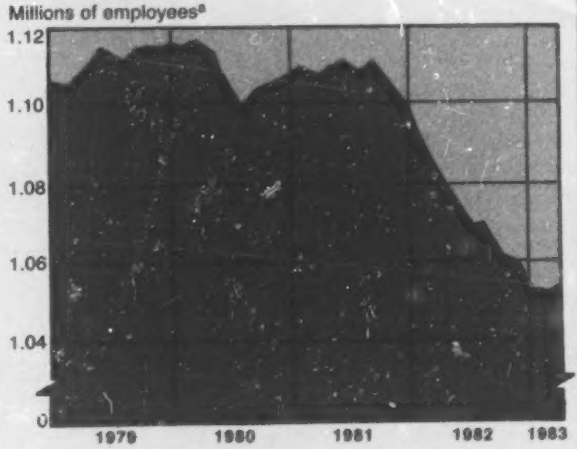
4 Employment in the U.S. Chemical Industry

Chemical companies sharply cut workforce

The number of workers in the U.S. chemical industry dropped throughout last year. And although the decline in employment apparently bottomed out early this year at about 1,050,000—the lowest level since late 1976—the industry cut its workforce more than 60,000 (nearly 6%), on a seasonally adjusted basis, since September 1981. About three quarters of the lost jobs have been among production or nonsupervisory workers in chemical plants. The most severe cutbacks have been made in plants that produce plastics and fibers or agricultural chemicals, where the drop in total employment during 1982 was about 8%.

Faced with lower demand and the need to slice operating costs, nearly all the major U.S. chemical producers have trimmed employment, with some of the larger firms cutting 5000 or more jobs. For several companies, in fact, among them Celanese, Monsanto, and Union Carbide, total employment now is less than it was a decade ago.

Employment in chemical production fell steadily throughout 1982



a Seasonally adjusted employment in U.S. chemicals and allied products industry; March and April 1983 figures are preliminary. **Source:** Department of Labor

INDUSTRIAL EMPLOYMENT: Lower throughout most of the chemical industry last year

	All employees[a] (thousands)				Production workers[a] (thousands)				Workweek[a,b] (hours)			
	1982	1981	1980	1972	1982	1981	1980	1972	1982	1981	1980	1972
All manufacturing	18,848	20,173	20,285	9151	12,782	14,021	14,214	14,045	38.9	39.8	39.7	40.5
Chemicals and allied products	1,074	1,107	1,107	1009	597	627	626	593	40.9	41.6	41.5	41.7
Industrial inorganic chemicals	154	160	161	141	82	87	87	87	40.4	41.5	41.5	42.0
Plastics materials and synthetics	183	195	205	229	118	129	137	149	40.6	42.0	41.4	42.0
Drugs	200	199	196	159	98	99	97	81	41.1	41.1	41.0	40.9
Soap, cleaners, and toilet goods	145	146	141	122	91	91	86	71	40.7	40.4	40.5	40.8
Paints and allied products	60	63	65	69	29	31	33	38	39.6	40.4	40.3	41.3
Industrial organic chemicals	174	179	174	143	88	90	88	78	41.9	42.8	42.8	42.1
Agricultural chemicals	67	71	72	56	41	44	45	36	42.0	43.0	43.4	42.4
Miscellaneous chemical products	92	95	93	90	51	54	53	54	40.5	41.3	41.0	41.4
Petroleum and coal products	207	216	198	195	124	135	125	125	43.9	43.2	41.8	42.7
Rubber and miscellaneous plastics products	698	736	727	630	535	569	559	495	39.6	40.3	40.0	41.1

a Domestic employment. b Workweek of production or nonsupervisory workers. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: More work with drugs than industrial chemicals

Thousands[a]	1982[b]	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Total, all industry	511.6	487.8	460.0	423.9	404.4	382.8	364.4	363.3	360.0	357.7	350.2
Chemicals and allied products	60.0	54.7	51.4	50.0	48.3	46.4	44.4	45.2	41.8	40.9	41.0
Industrial chemicals	24.3	21.6	20.9	21.4	21.3	20.6	20.1	21.1	19.1	19.1	19.1
Drugs and medicines	25.3	23.3	21.6	20.7	19.5	17.8	16.6	15.6	14.0	13.0	13.1
Other chemicals	10.4	9.8	8.9	7.9	7.5	8.0	7.8	8.5	8.7	8.8	8.8
Petroleum refining	15.9	13.0	10.8	10.1	9.9	8.9	8.6	8.4	8.2	8.2	8.3
Rubber products	na	na	na	8.1	7.9	9.1	8.6	8.4	7.7	7.5	6.7

a Full-time-equivalent number of R&D scientists and engineers in industry, as of January of each year. b Preliminary. na = not available. **Source:** National Science Foundation

CHEMICAL EMPLOYMENT: Companies trim their workforces for the second year in a row

Thousands	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Air Products	18.9	16.2	15.8	14.6	14.3	13.7	13.4	13.0	13.0	10.3
American Cyanamid	40.2	41.8	42.6	44.2	44.0	43.8	39.4	37.8	38.0	39.5
Celanese	36.7	35.9	36.5	33.3	33.2	32.1	31.9	37.0	38.8	37.4
Crompton & Knowles	2.3	2.5	2.8	3.0	3.2	3.1	3.0	2.2	2.4	2.5
Dow Chemical	56.6	63.8	56.8	55.9	53.5	53.2	53.0	53.0	53.3	49.8
Ethyl	14.0	14.5	15.0	16.0	16.5	16.0	16.0	17.0	18.0	14.0
FMC	33.9	38.9	39.0	41.0	40.4	37.9	33.2	33.2	34.1	31.7
Freeport-McMoRan	5.0	5.2	2.7	3.9	3.5	3.7	3.8	3.5	3.3	2.9
H. B. Fuller	4.0	3.3	3.4	3.4	3.3	3.0	2.8	2.6	2.3	2.1
W. R. Grace	82.2	89.0	91.7	82.1	68.5	68.7	63.8	65.3	79.1	75.7
Hercules	21.6	22.8	22.9	24.4	24.5	24.0	24.0	23.5	25.3	24.1
International Flavors	3.6	3.6	3.6	3.6	3.5	3.3	3.1	2.9	3.1	2.8
International Minerals	8.4	10.6	10.5	10.3	9.9	9.9	9.7	10.5	6.6	6.2
Lubrizol	4.3	4.2	4.2	3.9	3.8	3.6	3.6	3.6	3.5	3.3
Monsanto	52.2	57.4	61.8	63.9	62.9	61.5	61.9	59.2	60.9	58.3
Nalco Chemical	4.6	4.7	4.4	4.1	4.1	4.2	3.8	3.5	3.4	3.2
Olin	17.5	20.3	21.0	21.7	22.7	22.4	22.0	23.0	23.0	24.0
Pennwalt	9.5	10.7	12.8	13.3	14.0	13.9	13.9	14.3	14.8	13.9
Reichhold Chemicals	4.5	5.6	5.6	6.4	6.5	6.5	5.8	4.3	4.1	4.3
Rohm & Haas	11.5	13.5	13.2	13.3	13.1	13.0	13.3	13.8	14.2	13.5
Stauffer Chemical	11.0	12.2	13.4	13.8	13.1	13.0	13.0	13.1	12.5	12.0
Stepan Chemical	0.9	0.9	0.8	0.9	0.8	0.8	0.7	0.7	0.8	0.7
Union Carbide	103.2	110.3	116.1	115.8	113.4	113.7	113.1	106.5	109.6	109.4
TOTAL EMPLOYEES	**546.6**	**587.9**	**595.5**	**594.8**	**576.8**	**565.0**	**548.6**	**543.7**	**564.1**	**541.7**
ANNUAL CHANGE	**−7.0%**	**−1.3%**	**0.1%**	**3.1%**	**2.1%**	**3.0%**	**0.9%**	**−3.6%**	**4.1%**	**1.6%**
SALES PER EMPLOYEE ($ thousands, current)	**$109.4**	**$110.5**	**$103.5**	**$94.9**	**$89.8**	**$73.8**	**$68.5**	**$51.2**	**$57.3**	**$44.4**
SALES PER EMPLOYEE ($ thousands, constant 1972[a])	**$ 39.0**	**$ 40.0**	**$ 41.4**	**$44.5**	**$47.0**	**$39.9**	**$38.1**	**$29.4**	**$54.3**	**$42.0**

a Based on price index for chemicals and allied products. **Note:** Data for years prior to 1981 are not restated for acquisitions and similar adjustments.

WAGES: Workers making industrial chemicals earn more than those in other chemical areas

	Hourly earnings[a]				Weekly earnings[a]			
	1982	1981	1980	1972	1982	1981	1980	1972
All manufacturing	$ 8.50	$ 7.99	$ 7.27	$3.82	$330.65	$318.00	$288.62	$154.71
Chemicals and allied products	9.98	9.12	8.30	4.26	408.18	379.39	344.45	177.64
Industrial inorganic chemicals	11.04	10.16	9.07	4.58	446.02	421.64	376.41	192.36
Plastics materials and synthetics	9.87	9.01	8.21	4.08	400.72	378.42	339.89	171.36
Drugs	9.12	8.30	7.69	4.08	374.83	341.13	315.29	166.87
Soap, cleaners, and toilet goods	9.17	8.39	7.67	4.15	373.22	338.96	310.64	169.32
Paints and allied products	8.80	8.03	7.39	3.98	348.43	324.41	297.82	164.37
Industrial organic chemicals	11.85	10.72	9.67	4.93	496.52	458.82	413.88	207.55
Agricultural chemicals	9.68	8.89	8.12	3.85	406.56	382.27	352.41	163.24
Miscellaneous chemical products	9.22	8.44	7.75	4.09	373.41	348.57	317.75	169.33
Petroleum and coal products	12.46	11.38	10.10	4.96	546.99	491.62	422.18	211.79
Rubber and miscellaneous plastics products	7.63	7.16	6.52	3.61	302.15	288.55	260.80	148.37

a For production and nonsupervisory workers in domestic employment. **Source:** Department of Labor

5 Foreign Trade

World trade in chemicals slumps

World chemical trade last year responded to a world in recession by dropping 11% in dollar value. It was the second consecutive year in which world chemical trade, measured as exports, has declined. This is unprecedented in the post-World War II era. Since 1980, when world chemical exports hit their peak of $147 billion, they have slipped 16% to $125 billion last year. No major chemical exporting country has escaped. The U.S., Canada, Japan, Switzerland, and all of the major countries of the European Economic Community saw shipments to other nations decline from 1 to 18%.

For the U.S., the overall trade balance slipped further into the red as exports dropped 9% to $212 billion and imports went down only 7% to $244 billion. The result was a trade deficit of almost $32 billion, compared to a deficit of $27 billion in 1981. This rising trade deficit has trade officials concerned because it comes despite the fact that imports of oil, natural gas, and related products fell $18 billion last year.

Equally worrisome are the declines in the net U.S. trade position for machinery and equipment, agricultural products, textiles, and chemicals. Part of last year's problem was lower demand in major U.S. export markets, not only in the recession-laden industrialized countries, but in heavily indebted developing nations such as Mexico and Brazil. The other part was a strong U.S. dollar.

Nowhere is this more evident than in U.S. chemical trade. Chemical exports dropped 6% to $19.9 billion, while imports, despite a weak U.S. economy, managed to scratch out a gain of less than 1% to $9.5 billion. As a result, the chemical industry's trade surplus, which had reached an all-time high of $12 billion in 1980, slipped for the second consecutive year to $10.4 billion.

Very few chemical product areas came through 1982 without losing export markets. The most notable exception was medicinals and pharmaceuticals, exports of which increased 5% to $2.3 billion.

U.S. TOTAL TRADE BALANCE:

Drop in exports brings a bigger deficit

$ Billions	1982	1981	1980	1972
Exports[a]	$212.2	$233.7	$200.6	$49.6
Imports[b]	244.0	261.0	244.9	55.6
Trade balance	−31.8	−27.3	−24.3	−6.4

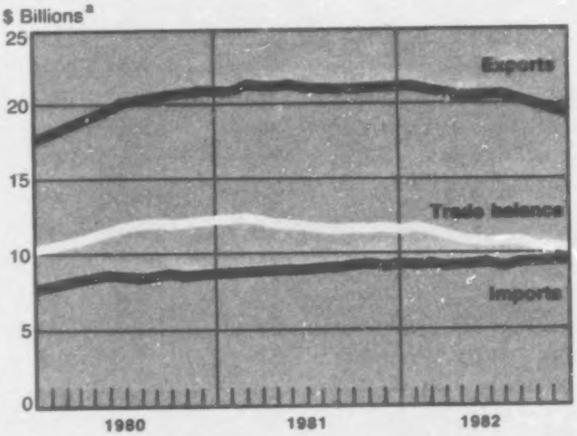
U.S. CHEMICAL TRADE BALANCE:

Surplus shrinks for second year in a row

$ Millions	1982	1981	1980	1972
Chemical exports[c]	$19,891	$21,187	$20,740	$4,134
Chemical imports[b]	9,494	9,446	8,594	2,015
Chemical trade balance	10,397	11,741	12,146	2,119

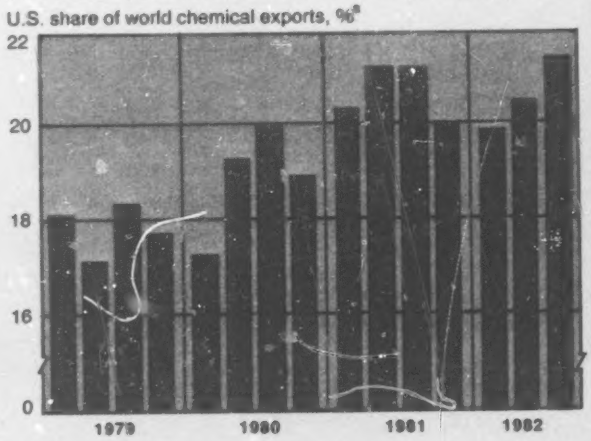
a Exports of domestic and foreign merchandise, excluding Department of Defense and Grant-Aid shipments; FAS (free along ship) value. b Customs value, except 1972, which is foreign value. c Excludes foreign re-exports. **Source:** Department of Commerce

Export fall cuts chemical trade balance . . .



a Running 12-month values for U.S. chemical exports, imports, and trade balance. **Source:** Department of Commerce

. . . but U.S. holds its share of world market



a U.S. chemical exports as a percentage of chemical exports from 15 major industrial nations, excluding exports to the U.S. **Source:** Department of Commerce

WORLD TRADE: Chemical exports drop

$ Millions	1982	1981	1980	1972
CHEMICAL EXPORTS				
World	$124,500[a]	$139,300[a]	$147,392	$29,137
U.S.	19,891	21,187	20,740	4,134
Canada	3,475	4,002	3,519	639
EC, 10 countries[b]	60,770	69,452	76,710	15,718
Belgium-Luxembourg	5,925	6,477	7,422	1,564
France	9,937	12,141	13,249	2,428
Italy	4,310	5,214	5,505	1,222
Netherlands	9,274	10,418	11,288	2,338
U.K.	8,872	10,831	12,303	2,404
West Germany	19,994	21,966	24,318	5,416
Switzerland	5,440	5,505	5,680	1,525
Japan	6,365	6,841	6,767	1,784
CHEMICAL IMPORTS				
U.S.	9,494	9,446	8,594	2,015
Canada	3,262	3,569	3,249	1,001
EC, 10 countries[b]	48,852	51,483	57,075	11,152
Belgium-Luxembourg	4,972	5,235	5,972	1,213
France	9,889	10,376	12,169	2,185
Italy	6,896	7,020	7,993	1,564
Netherlands	5,378	5,726	6,393	1,356
U.K.	6,427	7,260	7,310	1,630
West Germany	11,624	12,201	13,314	2,509
Switzerland	3,208	3,226	3,648	833
Japan	6,824	6,487	6,202	1,148

a C&EN estimates. b European Communities; historical data have been adjusted to reflect present 10 members. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Communities, individual country data

U.S. TRADE: Europe takes less, ships more

$ Millions	1982	1981	1980	1972
U.S. CHEMICAL EXPORTS				
Canada	$ 2,183	$ 2,478	$ 2,134	$ 693
Western Europe	5,940	6,155	6,429	1447
Eastern Europe	366	347	88	33
Communist Asia	497	406	386	2
Japan	2,530	2,349	1,964	313
Rest of Asia	2,600	2,597	2,782	348
Middle East	533	517	459	80
Latin America	3,670	4,469	4,846	908
Australasia	655	778	645	128
Africa	524	642	721	108
Other	393	449	286	74
TOTAL	**$19,891**	**$21,187**	**$20,740**	**$4134**
U.S. CHEMICAL IMPORTS				
Canada	$2596	$2916	$2494	$ 439
Western Europe	4174	3931	3953	940
Eastern Europe	151	131	195	15
Communist Asia	136	126	107	2
Japan	879	956	697	250
Rest of Asia	220	197	163	26
Middle East	99	110	58	11
Latin America	613	669	536	82
Australasia	286	186	206	99
Africa	225	117	62	17
Other	115	107	123	134
TOTAL	**$9494**	**$9446**	**$8594**	**$2015**

Source: Department of Commerce

U.S. TRADE, BY-PRODUCTS: Exports slump for most categories

$ Millions	Chemical exports[a]				Chemical imports[b]			
	1982	1981	1980	1972[c]	1982	1981	1980	1972[c]
Organic chemicals	$ 5,440	$ 5,929	$ 5,697	$1134	$2960	$2974	$2541	$ 517
Inorganic chemicals	1,969	2,286	2,106	414	1502	1573	1324	426
Radioactive and associated materials	1,132	988	833	181	1143	786	990	110
Dyeing, tanning, and coloring materials	162	175	186	57	213	226	195	114
Pigments, paints, and varnishes	332	349	304	100	103	102	89	16
Medicinals and pharmaceuticals	2,275	2,165	1,932	474	563	583	509	149
Flavors, perfumes, cosmetics, and toiletries	514	535	479	102	295	289	302	100
Cleaning and polishing materials	324	396	327	93	76	74	72	14
Fertilizers, manufactured	1,386	1,735	2,265	298	963	1181	1105	232
Explosives and pyrotechnics	90	90	87	28	67	61	59	21
Plastics and resins	3,650	3,809	3,884	696	766	780	647	177
Pesticides and disinfectants	607	544	553	d	265	283	264	d
Miscellaneous chemical products	2,010	2,187	2,087	556	579	534	497	140
TOTAL	**$19,891**	**$21,187**	**$20,740**	**$4134**	**$9494**	**$9446**	**$8594**	**$2015**

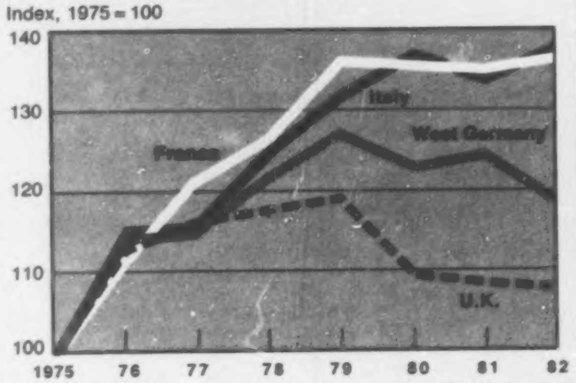
a Exports of domestic merchandise; FAS (free alongside ship) value. b General imports, FAS value. c As a result of statistical reclassification, data prior to 1978 are not comparable to those of subsequent years; C&EN has rearranged earlier data to make them as comparable as possible. d Included in miscellaneous. **Source:** Department of Commerce

6 Foreign Chemical Industries Western Europe

The chemical industry in Western Europe went through a difficult time in 1982. Demand was slack, competition keen, and selling prices under continued pressure. And production, where it was not actually below the previous year's level, generally was little changed.

As a result, financial results of the major West European chemical firms frequently were grim. Not necessarily as grim as the following statistics may suggest, however. Because all West European currencies continued to weaken against the U.S. dollar, translating monetary figures from local currency to dollars tends to penalize 1982 results relative to earlier years. In fact, only three of the 18 companies reported on page 58—Akzo, DSM, and Fisons—actually had lower sales, measured in local currency. And although most cut capital spending, outlays for R&D were higher all around.

Chemical production staggers in U.K., West Germany



CHEMICAL INDUSTRY TRENDS: Lower dollar values reflect recession and strong U.S. currency

$ Billions (U.S.)	1982	1981	1980	1979	1978
WEST GERMANY					
Sales	$48.5	$51.6	$59.2	$56.0	$44.6
Exports	22.9	23.8	26.0	24.0	18.4
Imports	13.0	13.3	14.6	13.2	9.5
Capital spending	2.8	3.1	3.8	3.3	2.8
Production Index (1975 = 100)	117.4	124.6	122.7	127.9	121.3
Price Index (1975 = 100)	130.1	125.2	115.2	106.8	99.2
Employees (thousands)	559	548	550	547	548
U.K.[a]					
Sales	$28.2	$37.6	$41.0	$35.6	$27.6
Exports	11.5	12.3	12.3	10.4	8.1
Imports	8.2	7.9	7.3	7.2	5.3
Capital spending	1.9	2.5	3.2	2.5	2.1
Production Index (1975 = 100)	107.9	108.3	109.1	119.2	117.6
Price Index (1975 = 100)	216.3	203.3	191.1	165.1	146.7
Employees (thousands)	338	395	430	441	439
FRANCE[a]					
Sales	$30.4	$33.4	$37.3	$32.9	$24.7
Exports	11.2	11.9	13.0	11.5	8.2
Imports	9.1	9.2	10.4	8.9	6.7
Capital spending	1.1	1.2	1.6	1.4	1.1
Production Index (1975 = 100)	136.8	135.1	136.0	136.8	126.3
Price Index (1975 = 100)	204.6	182.1	159.6	134.1	116.2
Employees (thousands)	286	289	296	301	306
ITALY					
Sales	$22.7	$24.1	$28.7	$23.7	$17.9
Exports	5.0	5.6	5.9	5.2	3.9
Imports	7.4	7.8	9.0	7.9	5.4
Capital spending	1.1	1.1	1.9	1.7	1.3
Production Index (1975 = 100)	137.6	133.5	137.5	132.6	125.0
Price Index (1975 = 100)	242.6	218.7	195.4	162.0	131.8
Employees (thousands)	260	271	289	291	292
BELGIUM					
Sales	$14.1	$15.3	$16.6	$14.4	$10.0
Exports	8.9	9.2	10.4	9.3	7.2
Imports	6.3	6.4	7.5	6.6	5.0
Capital spending	0.3	0.4	0.5	0.5	0.5
Production Index (1975 = 100)	131.7	129.7	125.4	133.4	123.4
Price Index (1975 = 100)	152.6	134.1	121.1	107.1	104.2
Employees (thousands)	88	88	90	82	89

$ Billions (U.S.)	1982	1981	1980	1979	1978
NETHERLANDS					
Sales	$12.5	$13.6	$14.3	$13.5	$10.0
Exports	11.3	11.9	13.0	11.8	8.6
Imports	6.7	7.1	7.9	7.0	5.1
Capital spending	0.6	0.6	0.7	0.6	0.8
Production Index (1975 = 100)	131.0	133.0	130.0	136.0	124.0
Price Index (1975 = 100)	140.0	143.0	125.0	114.0	103.0
Employees (thousands)	90	91	91	92	94
SPAIN					
Sales	$15.2	$15.7	$17.3	$15.4	$11.1
Exports	2.2	2.3	2.5	2.0	1.2
Imports	2.9	3.1	3.5	3.1	2.1
Capital spending	0.4	0.4	0.7	0.6	0.4
Production Index (1975 = 100)	132.2	128.5	132.3	135.0	na
Price Index (1975 = 100)	258.5	232.5	202.0	167.0	na
Employees (thousands)	243	244	244	245	215
SWITZERLAND					
Sales	$6.6	$6.7	$6.8	$6.6	$6.0
Exports	5.4	5.4	5.6	5.3	4.7
Imports	3.3	3.3	3.7	3.2	2.4
Production index (1975 = 100)	135.5	137.1	130.5	128.4	123.1
Price Index (1975 = 100)	103.6	101.8	97.0	90.7	89.1
Employees (thousands)	na	63	62	62	62
SWEDEN					
Sales	$4.0	$4.1	$4.3	$3.9	$3.0
Exports	1.6	1.6	1.7	1.5	1.2
Imports	2.6	2.5	2.9	2.7	2.0
Capital spending	0.3	0.3	0.4	0.4	0.3
Production Index (1975 = 100)	123.4	108.0	106.3	111.3	108.2
Price Index (1975 = 100)	184.8	167.6	154.0	134.0	118.0
Employees (thousands)	44	41	39	40	40
NORWAY					
Sales	$2.0	$1.9	$2.1	na	na
Exports	1.0	1.5	1.2	$0.9	$0.7
Imports	0.9	1.0	1.1	1.0	0.8
Capital spending	0.1	0.1	0.2	0.1	0.3
Production Index (1975 = 100)	121.4	122	120	118	102
Price Index (1975 = 100)	191	141	131	116	103
Employees	18	17	17	17	17

a Excludes fibers. na = not available. **Sources:** National chemical federations and Conseil Européen des Fédérations de l'Industrie Chimique

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MAN-MADE FIBERS: Output dropped last year throughout almost all of Western Europe

	1982		1981		1980		1979		1978		Change, 1981–82	
Millions of lb	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics	Cellulosics
West Germany	1589	314	1735	322	1619	304	1725	295	1649	293	−8%	−2%
Italy	1090[b]	102	1115[b]	133	896[b]	144	988	156	952	190	−2	−23
Spain	507	95	518	111	452	116	466	128	416	133	−2	−14
U.K.	506[c]	265[d]	612[c]	298[d]	700[c]	364[d]	838	504	885	472	−17	−11
France	436	100	444	119	423	146	493	169	542	163	−2	−16
Benelux countries	193	124	228	144	230	148	286	165	306	165	−15	−14
Switzerland	184	0	197	0	186	4	185	7	194	9	−7	—
Ireland	115	0	110	0	92	0	86	0	68	0	5	—
Portugal	na	na	75	9	67	6	68	7	62	5	—	—
Austria	51	251	53	257	56	255	62	242	67	236	−4	−2

a Excludes polypropylene filament unless otherwise indicated. b Includes polypropylene filament. c Includes cellulose acetate filament. d Excludes cellulose acetate filament. na = not available. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: Volume fell last year more often than it rose

Millions of lb	1982	1981	1980	1979	Change 1981–82
FRANCE					
Sulfuric acid	8858	9917	10,894	10,905	−11%
Hydrochloric acid	1514	1544	1,487	1,575	−2
Phosphoric acid	458	400	445	417	15
Chlorine	2759	2711	2,765	2,829	2
Sodium hydroxide	2939	2893	2,946	3,100	2
Ammonia	4180	4950	4,587	4,730	−16
Benzene	1133	1100	1,204	1,392	3
Toluene	69	124	140	190	−44
Xylenes	113	251	172	228	−55
Ethylene	4112	4085	4,561	4,946	1
Propylene	2277	2212	2,174	2,543	3
Butadiene	569	586	572	659	−3
Acetone	241	234	218	271	3
Formaldehyde	175	220	254	309	−20
Methanol	753	765	757	777	−2
Polyethylenes	1938	1944	2,364	2,580	0
Polypropylene	692	656	464	444	5
Polystyrene	680	577	559	590	18
Polyvinyl chloride	1729	1563	1,596	1,722	11
Synthetic rubber	1045	1070	1,124	1,091	−3
Phosphate fertilizers (P_2O_5)	2447	2590	2,965	2,999	−6
ITALY					
Sulfuric acid	5153	5597	6,220	6,502	−8%
Nitric acid	2203	2212	2,232	2,353	0
Phosphoric acid	936	979	1,044	1,985	−4
Chlorine	1569	1556	1,821	1,907	1
Sodium hydroxide	1854	1857	2,097	2,169	0
Ammonia	2769	3239	3,770	3,901	−15
Benzene	864	932	989	1,165	−7
Toluene	592	613	631	807	−3
Xylenes	590	564	625	713	5
Ethylene	2006	2011	2,364	2,598	0
Propylene	1024	1083	1,426	1,490	−5
Butadiene	349	366	403	365	−5
Phthalic anhydride	300	309	310	338	−3
Formaldehyde	228	240	288	296	−5
Polyethylenes	1157	1223	1,645	1,609	−5
Polystyrene	678	637	714	747	6
Polyvinyl chloride	1214	1282	1,480	1,534	−5
Synthetic rubber	478	535	569	640	−11
U.K.					
Sulfuric acid	5688	6360	7,440	7,692	−11%
Hydrochloric acid[a]	264	257	302	347	3
Nitric acid	6784	6541	6,215	6,399	4
Chlorine	1944	1916	2,004	2,262	1
Benzene	1377	1799	1,978	2,523	−23
Toluene	372	394	374	646	−6
Ethylene	2376	2718	2,409	2,714	−13
Propylene	1705	1621	1,260	1,685	5
Butadiene	516	457	422	500	13
Acetone	293	245	270	323	20
Ethanol	404	353	353	na	14
Formaldehyde	236	249	273	303	−5
Phenol	301	241	310	392	25
Phthalic anhydride	161	134	101	207	20
Thermoplastics	3044	2889	2,911	3,659	5
Polyethylenes	916	1000	957	1,069	−8
Polypropylene	486	435	418	581	12
Polystyrene	298	316	345	466	−6
Polyvinyl chloride	779	693	770	957	12
Synthetic rubber	419	418	466	611	0
Nitrogen fertilizers (N)[a]	2708	2837	2,552	2,973	−5
Phosphate fertilizers (P_2O_5)[a]	725	741	764	1,001	−2
WEST GERMANY					
Sulfuric acid	8334	9018	9,054	9,440	−8%
Hydrochloric acid	1865	1953	1,960	2,080	−5
Nitric acid	5040	6356	6,994	6,912	−21
Chlorine	6253	6629	6,592	7,044	−6
Sodium hydroxide	6318	6687	6,595	7,082	−6
Sodium sulfate	472	561	496	464	−16
Sodium carbonate	2432	2616	3,104	3,082	−7
Ammonia	3454	4316	4,496	4,755	−20
Ammonium carbonate	2432	2616	3,104	3,082	−7
Benzene	2258	2027	2,022	2,214	11
Toluene	590	578	573	657	2
Xylenes	1012	1071	783	1,085	−6
Ethylene	5808	6357	6,744	7,807	−9
Propylene	3259	3550	3,501	4,057	−8
Ethylene oxide	866	955	847	966	−9
Ethylene glycol	404	487	459	559	−17
Acetaldehyde	571	670	736	892	−15
Acetic acid	562	646	631	758	−13
Ethanol	220	222	238	228	−1
Formaldehyde	1070	1117	1,059	1,075	−4
Methanol	1559	1524	1,810	1,916	2
Phthalic anhydride	439	474	494	588	−7
Polyethylenes	2473	2639	3,080	3,472	−6
Polyvinyl chloride	1902	2021	2,097	2,387	−6
Synthetic rubber	844	873	958	921	−3
Nitrogen fertilizers (N)	1464	2191	2,449	2,144	−33
Phosphate fertilizers (P_2O_5)	595	732	841	774	−19

a Manufacturers' sales. **Sources:** Government agencies for each country

6 Foreign Chemical Industries Western Europe

COMPANY RESULTS: Despite recession some firms bolstered earnings last year

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Hoechst (West Germany)						
1982	$14,397.5	$130.5	0.9%	$ 850.6	$642.4	182.2
1981	15,236.7	188.5	1.2	870.4	670.4	184.7
1980	16,436.8	305.5	1.9	1053.8	714.8	186.9
1979	14,797.8	355.2	2.4	893.4	624.0	182.7
Bayer (West Germany)						
1982	$14,335.0	$ 26.3	0.2%	$ 846.9	$637.9	179.4
1981	14,930.1	228.8	1.5	1123.5	822.1	180.9
1980	15,837.9	401.1	2.5	1461.0	681.9	181.6
1979	14,208.7	237.7	1.7	1224.0	603.3	181.0
BASF (West Germany)						
1982	$13,368.7	$113.2	0.8%	$ 824.3	$483.1	115.9
1981	14,055.8	162.4	1.2	911.1	484.1	116.6
1980	15,236.8	197.3	1.3	1011.5	545.6	116.5
1979	14,150.8	338.3	2.4	989.6	487.4	117.2
Imperial Chemical Industries (U.K.)						
1982	$12,886.2	$253.9	2.0%	$ 511.4	$427.3	123.8
1981	13,348.9	389.5	2.9	833.7	464.5	132.4
1980	13,290.7	302.3[a]	2.3	1683.7	493.0	143.2
1979	11,397.0	970.2	8.5	1613.6	392.8	148.2
Montedison (Italy)						
1982	$6,665.9	($529.9)[b]	—	$324.5	$170.7	84.2
1981	7,851.3	(564.6)[b]	—	377.3	175.0	94.2
1980	9,090.0	(523.4)[b]	—	450.9	205.6	105.5
1979	8,222.6	14.4	0.2%	454.9	190.1	114.7
DSM (Netherlands)						
1982	$6,806.0	($70.3)[b]	—	$165.5	$63.7	28.6
1981	7,330.4	40.4	0.6%	196.8	64.0	30.0
1980	7,496.5	12.6	0.2	258.3	75.4	31.4
1979	6,343.3	44.3	0.7	266.7	67.2	31.8
Ciba-Geigy (Switzerland)						
1982	$6,802.0	$306.4	4.5%	$427.6	$578.8	79.4
1981	6,938.3	265.8	3.8	446.4	549.0	80.2
1980	7,134.1	182.6	2.6	510.8	561.1	81.1
1979	5,958.4	197.0	3.3	360.2	496.4	80.2
Rhône-Poulenc (France)						
1982	$5,661.5	($48.4)[b]	—	$359.2	$274.0	81.8
1981	5,932.4	(105.3)[b]	—	447.8	279.8	89.3
1980	7,139.2	($77.3)[b,c]	—	572.1	323.2	95.4
1979	7,948.5	186.1	2.3%	517.7	292.0	106.7
Akzo (Netherlands)						
1982	$5,301.1	$ 79.0	1.5%	$273.4	$232.2	73.7
1981	5,790.4	89.6	1.5	277.2	234.0	77.8
1980	6,257.8	85.4	1.4	324.1	258.8	83.1
1979	5,977.6	143.8	2.4	299.5	228.9	83.0

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Solvay (Belgium)						
1982	$3,891.3	$ 56.8	1.5%	$153.8	$131.1	45.4
1981	4,239.7	(20.5)[b]	—	247.6	143.4	48.2
1980	4,734.9	67.6	1.4	368.0	154.0	49.1
1979	4,126.2	175.2	4.3	288.7	98.1	46.2
Hoffmann-La Roche (Switzerland)						
1982	$3,499.2	$138.5	4.0%	$346.7	$453.5	46.5
1981	3,456.4	129.1	3.7	308.6	414.2	44.0
1980	3,506.5	138.9	4.0	309.0	415.0	43.6
1979	3,127.0	131.9	4.2	318.1	389.2	42.7
Norsk Hydro (Norway)						
1982	$3,185.9	$123.1	3.9%	$509.3	na	19.6
1981	3,045.6	171.4	5.6	370.7	na	15.1
1980	2,854.0	207.1	7.3	326.3	na	13.5
1979	1,799.2	52.0	2.9	220.2	na	11.7
Sandoz (Switzerland)						
1982	$2,981.8	$134.5	4.5%	$124.6	$244.8	37.3
1981	2,941.8	115.8	3.9	155.6	236.2	36.4
1980	2,934.1	121.0	4.1	153.9	248.5	35.5
1979	2,677.1	104.2	3.9	124.7	232.5	35.3
BOC International (U.K.)						
1982	$2,686.9	$131.3	4.9%	$388.3	na	38.4
1981	3,066.6	116.6	3.8	316.0	na	42.1
1980	2,777.9	109.5	3.9	319.3	na	44.7
1979	2,609.3	94.7	3.6	280.7	na	48.6
Albright & Wilson (U.K.)						
1982	$ 929.6	$13.7	1.5%	$33.6	na	7.2
1981	1,019.9	11.0	1.1	51.7	na	8.9
1980	986.0	(4.0)[b]	—	70.5	na	9.2
1979	838.4	36.1	4.3	69.2	na	10.2
Fisons (U.K.)						
1982	$ 613.8	$25.4	4.1%	$ 3.2	$29.4[d]	7.5
1981	1,002.8	7.8	0.8	3.9	31.2[d]	9.8
1980	1,055.1	(3.3)[b]	—	4.9	32.6	11.3
1979	919.3	28.1	3.1	10.4	30.6	13.2
UCB (Belgium)						
1982	$606.6	$ 9.4	1.6%	$20.0	$17.2	6.7
1981	686.0	4.3	0.6	31.0	18.7	7.8
1980	786.4	8.1	1.0	38.2	21.9	8.1
1979	695.4	16.5	2.4	21.0	19.6	8.3
Laporte Industries (U.K.)						
1982	$425.5	$20.1	4.7%	$21.7	na	3.5
1981	435.5	12.8	2.9	20.3	na	3.9
1980	457.0	7.4	1.6	37.2	na	4.7
1979	403.6	17.4	4.3	34.0	na	4.8

a Excludes extraordinary write-off for company restructuring of $348.8 million. b Deficit. c Excludes extraordinary write-off for company restructuring of $383 million. d C&EN estimate. na = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:									
	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1982	45.69 francs	6.57 francs	1353 lire	2.67 guilders	6.45 crowns	109.66 pesetas	6.28 crowns	2.03 francs	0.571 pound	2.43 marks
1981	37.13 francs	5.44 francs	1137 lire	2.50 guilders	5.74 crowns	92.31 pesetas	5.06 crowns	1.96 francs	0.493 pound	2.26 marks
1980	29.24 francs	4.23 francs	856 lire	1.99 guilders	4.94 crowns	71.71 pesetas	4.23 crowns	1.67 francs	0.430 pound	1.82 marks
1979	29.32 francs	4.25 francs	831 lire	2.01 guilders	5.06 crowns	67.12 pesetas	4.29 crowns	1.66 francs	0.471 pound	1.83 marks
1978	31.67 francs	4.50 francs	847 lire	2.16 guilders	5.22 crowns	76.00 pesetas	4.52 crowns	1.79 francs	0.521 pound	1.99 marks

Foreign Chemical Industries Japan ⑥

Japan's basic petrochemicals industry, officially designated as "structurally depressed," is undergoing what the Japanese euphemistically call "structural reform." With the government's blessing—indeed, its urging—Japan's major petrochemical companies are joining together to agree upon scrapping excess production capacity and to form joint sales organizations.

Ethylene's performance tells the story. Production last year was 3.6 million metric tons, down 25% from its high of 4.8 million metric tons in 1979. With capacity at just over 6 million metric tons, a capacity-cutting program is easy to understand.

The picture with many other major petrochemicals is not much prettier. Caught between rising raw material costs and inability to raise prices in a depressed market, Japanese chemical companies feel the pinch on their earnings as they resort to cutthroat competition to maintain market share.

WORLD TRADE: Chemical surplus ends

$ Millions	1982	1981	1980	1979
Total exports	$138,831	$152,030	$129,807	$103,032
Total imports	131,931	143,290	140,528	110,372
Chemical exports	6,365	6,841	6,767	6,100
Chemical imports	6,824	6,487	6,202	5,178

Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: Stagnation continues

Index, 1975 = 100	1982	1981	1980	Change 1981–82
All chemicals				
Production	148.9	144.9	144.7	3%
Shipments	139.7	137.7	139.9	1
Inventories	112.3	112.7	113.5	0
Petrochemicals				
Production	123.7	126.4	133.6	−2
Shipments	123.7	126.3	132.1	−2
Inventories	125.1	124.5	132.6	0
Plastics				
Production	143.3	142.4	149.3	1
Shipments	142.5	142.6	149.1	0
Inventories	105.9	111.2	116.2	−5
Synthetic fibers				
Production	123.6	126.0	128.7	−2
Shipments	127.9	131.7	131.7	−3
Inventories	93.7	81.3	77.1	15
Synthetic rubber				
Production	118.0	128.1	138.7	−8
Shipments	111.2	120.7	129.7	−8
Inventories	114.4	118.5	125.1	−3
Fertilizer				
Production	68.1	72.6	85.5	−6
Shipments	76.8	79.1	93.6	−3
Inventories	61.0	75.0	72.0	−19
All manufacturing				
Production	148.8	147.2	142.8	1
Shipments	139.9	139.9	137.1	0
Inventories	116.3	114.4	110.4	2

Source: Ministry of International Trade & Industry

PRODUCTION: Most chemicals down in 1982

Thousands of metric tons unless otherwise indicated	1982	1981	1980	1979	Change 1981–82
ORGANIC CHEMICALS					
Acetaldehyde	279	324	432	583	−14%
Acetic acid	353	365	418	502	−3
Acetone	229	225	235	254	2
Acrylonitrile	489	477	469	579	3
Benzene	1814	1899	2060	2178	−4
Butadiene	522	518	574	670	1
Butyl alcohol	234	237	222	252	−1
Caprolactam	388	427	443	437	−9
Cyclohexane	426	475	500	509	−10
Dioctylphthalate	221	223	241	259	−1
Ethylene	3588	3644	4176	4781	−2
Ethylene dichloride	1548	1650	2060	2110	−6
Ethylene glycol	385	411	492	572	−6
Ethylene oxide	471	478	529	593	−1
Methanol, refined	626	734	836	940	−15
Octyl alcohol, synthetic	226	239	241	264	−5
Phenol, synthetic	211	214	215	244	−1
Phthalic anhydride	254	254	235	284	0
Propylene	2545	2538	2636	3096	0
Propylene glycol	185	171	163	168	8
Styrene	1086	1095	1114	1238	−1
Terephthalic acid	649	635	601	613	2
Toluene	803	821	889	938	−2
Toluene diisocyanate	67	64	67	66	5
Xylene	1225	1202	1195	1317	2
Urea	1187	1483	1770	2083	−20
INORGANIC CHEMICALS					
Ammonium chloride	486	584	683	753	−17
Ammonium sulfate	1689	1817	1879	1883	−7
Calcium carbide	483	495	550	570	−2
Calcium superphosphate	527	483	591	568	9
Carbon black	504	557	575	538	−10
Chlorine, liquid	794	764	763	729	4
Hydrochloric acid	551	565	570	528	−2
Nitrogen, millions of cu m	5236	5147	4586	4150	2
Oxygen, millions of cu m	6493	6603	6854	7070	−2
Sodium carbonate	1162	1178	1357	1355	−1
Sodium hydroxide	2792	2872	3159	3021	−3
Sodium silicate	650	692	712	714	−6
Sulfuric acid	6530	6572	6777	6581	−1
Titanium dioxide	184	176	173	185	5
PLASTICS					
Phenolic resins	281	294	304	300	−4
Polyethylene	1674	1671	1860	2165	0
Polypropylene	941	959	927	1023	−2
Polystyrene	1190	1183	1129	1227	1
Polyvinyl chloride	1218	1129	1429	1592	8
DYES, synthetic	54	50	51	60	8
RUBBER CHEMICALS, organic	39	43	46	45	−9
RUBBER, synthetic	931	1010	1094	1107	−8

Source: Ministry of International Trade & Industry

COMPANY RESULTS: Profits improve for some firms, but margins remain slim

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Mitsubishi Chemical Industries[a]					
1982	$3180	($25.4)[b]	—	$3325	8.4
1981	3399	13.5	0.4%	3374	8.3
1980	3730	39.6	1.1	3739	8.0
1979	2742	25.5	0.9	2996	8.2
Asahi Chemical Industry					
1982	$2741	$42.2	1.6%	$2809	14.0
1981	2663	48.4	1.8	2895	13.6
1980	2800	64.4	2.3	2825	13.6
1979	2168	47.2	2.2	2266	13.8
Sumitomo Chemical[c]					
1982	$2671	$21.2	0.8%	$2510	9.1
1981	2881	10.5	0.4	2699	9.6
1980	3167	45.0	1.4	2856	9.7
1979	2202	45.0	2.0	2017	9.9
Toray Industries					
1982	$2417	$46.6	1.9%	$2385	13.9
1981	2503	48.3	1.9	2446	13.9
1980	2494	57.9	2.3	2408	13.8
1979	1924	55.7	2.9	2010	13.9
Mitsui Toatsu Chemicals					
1982	$1781	$ 0.0	0.0%	$1790	5.7
1981	1948	(22.3)[b]	—	1858	7.4
1980	1965	(32.8)[b]	—	1941	7.7
1979	1624	36.3	2.2	1613	7.8
Teijin					
1982	$1770	$28.4	1.6%	$1953	7.1
1981	2072	24.1	1.2	2090	7.2
1980	2111	26.3	1.3	2093	7.3
1979	1613	26.8	1.8	1815	7.2
Dainippon Ink & Chemicals					
1982	$1620	$17.8	1.1%	$1426	5.9
1981	1657	18.8	1.1	1511	5.9
1980	1654	22.1	1.3	1446	5.8
1979	1301	18.4	1.4	1124	5.5
Showa Denko[c]					
1982	$1569	$ 4.2	0.3%	$2004	5.3
1981	1729	2.6	0.2	2102	5.4
1980	2083	35.7	1.7	2276	5.5
1979	1496	27.3	1.8	1475	4.3
Mitsubishi Petrochemical[c]					
1982	$1505	($42.4)[b]	—	$1767	3.5
1981	1667	(6.3)[b]	—	1802	3.9
1980	1900	16.2	0.9%	1908	3.8
1979	1366	16.5	1.2	1384	3.9
Sekisui Chemical					
1982	$1314	$10.6	0.8%	$1238	6.2
1981	1338	7.9	0.6	1322	6.1
1980	1420	17.0	1.2	1359	6.1
1979	1195	17.3	1.5	1107	6.0
Mitsui Petrochemical Industries					
1982	$1187	($8.5)[b]	—	$1412	4.5
1981	1260	(8.6)[b]	—	1455	4.6
1980	1339	10.8	0.8%	1474	4.6
1979	1167	23.2	2.0	1127	4.8
Unitika					
1982	$1102	$0.2	0.0%	$1113	6.2
1981	965	0.4	0.0	1135	6.2
1980	1011	4.1	0.4	1229	6.3
1979	785	2.3	0.3	1024	6.5

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Kyowa Hakko Kogyo[c]					
1982	$920	$21.6	2.4%	$802	5.0
1981	928	18.8	2.0	782	4.9
1980	945	14.9	1.6	749	5.0
1979	694	12.1	1.7	585	4.8
Mitsubishi Gas Chemical					
1982	$916	$ 9.8	1.1%	$884	3.8
1981	931	20.8	2.2	938	3.8
1980	898	30.7	3.4	948	3.8
1979	714	19.7	2.8	740	3.8
Toyo Soda Mfg.					
1982	$890	$ 0.0	0.0%	$1131	4.3
1981	927	(60.4)[b]	—	1209	4.9
1980	942	5.2	0.6	1251	5.0
1979	809	14.5	1.8	977	4.9
Mitsubishi Rayon					
1982	$835	$10.1	1.2%	$824	3.6
1981	894	11.0	1.2	803	3.5
1980	882	11.1	1.3	814	3.5
1979	676	23.6	3.5	703	3.4
Kuraray					
1982	$820	$5.1	0.6%	$904	6.3
1981	879	8.2	0.9	928	6.3
1980	956	7.5	0.8	984	5.7
1979	762	2.7	0.4	824	5.2
Denki Kagaku Kogyo					
1982	$801	$ 8.5	1.1%	$1091	4.0
1981	867	10.4	1.2	1092	4.0
1980	893	10.8	1.2	1078	4.0
1979	761	17.1	2.3	881	4.0
Hitachi Chemical					
1982	$746	$9.5	1.3%	$465	4.4
1981	753	9.9	1.3	451	4.3
1980	746	8.2	1.1	440	4.3
1979	596	8.6	1.4	336	4.1
Japan Synthetic Rubber					
1982	$695	$ 5.5	0.8%	$709	2.7
1981	737	3.0	0.4	720	2.7
1980	779	8.2	1.1	761	2.6
1979	542	12.6	2.3	579	2.6
Tokuyama Soda					
1982	$691	$4.2	0.6%	$669	2.5
1981	768	4.4	0.6	691	2.5
1980	767	5.2	0.7	682	2.4
1979	616	5.8	0.9	546	2.4
Kanegafuchi Chemical Industry					
1982	$683	$ 6.8	1.0%	$546	3.3
1981	719	5.9	0.8	583	3.2
1980	776	13.3	1.7	612	3.1
1979	661	16.0	2.4	466	3.0
Daicel Chemical					
1982	$664	$14.4	2.2%	$634	3.1
1981	702	12.5	1.8	656	3.1
1980	677	12.6	1.9	659	3.1
1979	501	15.7	3.1	467	3.1
Shin Etsu Chemical[d]					
1982	$657	$ 8.5	1.3%	$601	2.5
1981	674	8.5	1.3	629	2.4
1980	653	11.5	1.8	600	2.3
1979	551	14.3	2.6	418	2.2

a Fiscal year ends Jan. 31. b Deficit. c Fiscal year ends Dec. 31. d Fiscal year ends May 31. **Note:** Fiscal years ending March 31 of each year unless otherwise specified. Fiscal year 1982 data are estimates. Results were converted from yen to U.S. dollars on the following basis: fiscal year 1982: $1.00 = 235.8 Y; fiscal year 1981: $1.00 = 222.4 Y; fiscal year 1980: $1.00 = 212.9 Y; fiscal year 1979: $1.00 = 249.4 Y. Year-to-year changes in sales, net income, and assets are affected by fluctuations in the currency exchange rate. **Source:** Toyo Keizai Shinposha

Foreign Chemical Industries Canada 6

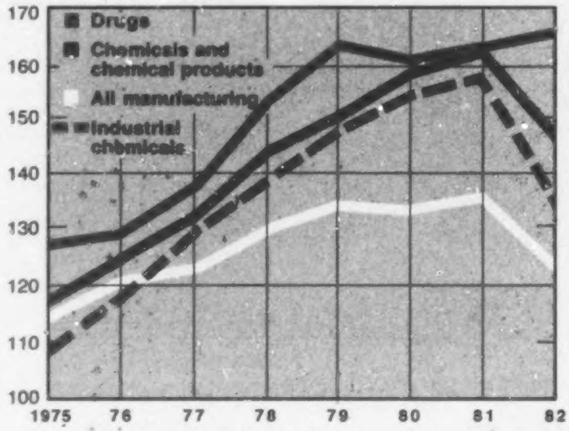
Three strikes and the Canadian chemical industry was out last year.

Strike one was the worst recession that Canada has seen since the Great Depression. Strike two was a downturn in world markets that the Canadian industry depends upon to soak up output from the world-scale plants that it has built in recent years. Strike three was the national energy policies that drove up prices of oil, natural gas, and petrochemical feedstocks when they were declining virtually everywhere else in the world.

The results were predictable. Sales were down. Profits were down. And production cutbacks struck across the board. Fertilizer materials, basic and intermediate petrochemicals, plastics, and inorganics all felt the impact of the domestic and worldwide economic slowdown. Chemical exports dropped almost 12% to $4 billion (Canadian). Several chemical companies chalked up the worst financial results of their history, and at least two companies, Petrosar and Petromont, were on the verge of collapse without government aid.

Production of chemicals nosedives

Index of volume,[a] 1971 = 100



a Gross domestic product. **Source:** Statistics Canada

COMPANY RESULTS: Red ink for most firms

$ Millions (Canadian)	Sales	Net income[a]	Profit margin	Capital expenditures	Employees (thousands)
C-I-L INC.[b]					
1982	$1059.8	$15.2	1.4%	$85.5	6.9
1981	1149.9	54.3	4.7	94.1	7.8
1980	1004.2	51.5	5.1	70.2	8.3
1979	880.0	36.3	4.1	84.4	8.0
CELANESE CANADA					
1982	$ 323.9	($5.6)[c]	—	$59.8	3.4
1981	373.0	20.4	5.4%	87.7	3.5
1980	336.2	24.2	7.2	55.1	4.2
1979	353.6	21.2	6.0	24.4	4.4
DU PONT CANADA					
1982	$ 980.0	($7.4)[c]	—	$24.0	5.4
1981	1139.1	33.5	2.9%	47.0	6.1
1980	995.3	42.6	4.3	53.2	5.9
1979	879.6	58.9	6.7	23.3	5.6
POLYSAR					
1982	$1330.0	($30.5)[c]	—	$207.0	6.6
1981	1049.0	74.0	7.1%	58.3	5.4
1980	1171.0	73.4	6.3	86.2	6.1
1979	1136.4	22.0	1.7	199.3	7.1
UNION CARBIDE CANADA					
1982	$ 691.3	($17.9)[c]	—	$ 67.6[d]	4.5
1981	827.3	36.1	4.4%	100.0	5.0
1980	794.8	79.6	10.0	58.9	5.0
1979	685.9	57.8	8.4	30.1	4.8

a Excluding extraordinary gains and losses. b Name changed from Canadian Industries Ltd. on Jan. 1, 1980. c Deficit. d Excludes $50.9 million spent on Prentiss, Alta., ethylene glycol plant that was transferred to another Union Carbide subsidiary.

TRADE BALANCE: Big gain for total surplus

$ Millions (Canadian)	1982	1981	1980	1979
Exports[a]	$81,434	$81,203	$74,446	$64,317
Imports	67,355	79,129	69,274	62,871
Trade balance	14,109	2,074	5,172	1,446

Lower exports hurt chemical surplus

$ Millions (Canadian)	1982	1981	1980	1979
Exports[a]	$4073	$4605	$4056	$3322
Imports	3584	3814	3354	3240
Trade balance	489	791	702	82

a Domestic exports only. **Source:** Statistics Canada

PRODUCTION: Cutbacks almost everywhere

Thousand of metric tons	1982	1981	1980	1979	Change 1981-82
Ammonia, anhydrous	2509	2654	2555	2405	−5%
Ammonium nitrate	1018	1212	873	914	−16
Ammonium phosphate	888	1355	1466	1336	−34
Benzene	504	571	604	492	
Chlorine	1233	1292	1303	1031	−5
Ethylene	1013	1330	1184	1014	−24
Hydrochloric acid	135	186	177	154	−27
Phosphoric acid, 100% P_2O_5	503	744	808	748	−32
Polyesters, unsaturated	19	26	27	32	−27
Polyethyene	571	633	641	628	−10
Polystyrene	133	123	110	124	8
Polyvinyl chloride	194	222	190	145	−13
Sodium chlorate	264	251	245	224	4
Sodium hydroxide	1367	1458	1459	1138	−6
Sulfuric acid, 100%	3131	4117	4295	3666	−24
Urea	1231	1303	1274	1212	−6

Source: Statistics Canada

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SHIPMENTS: Lower dollar volume reflects last year's business recession

$ Millions (Canadian)	Shipments, monthly average											Average annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1981-82	1972-82
All manufacturing	$15,249.8	$15,776.0	$13,913.2	$12,520.7	$10,743.7	$9070.6	$8190.4	$7371.6	$6871.2	$5563.1	$4687.2	−3%	13%
Chemicals and chemical products	1,036.8	1,059.4	929.7	791.9	663.3	535.6	475.3	425.6	383.9	291.9	246.2	−2	15
Petroleum and coal products	1,723.0	1,633.3	1,206.7	1,003.0	837.9	711.0	576.8	496.1	432.1	256.1	203.4	5	24
Rubber and plastics products	359.1	379.8	334.7	300.3	250.1	211.0	192.7	162.9	152.8	131.4	109.7	−5	13
Paper and allied products	1,212.3	1,294.5	1,185.5	1,032.0	839.5	744.8	685.7	594.2	639.7	439.2	367.8	−6	13

Source: Statistics Canada

PRICES: Inflation continues, but generally at a more moderate rate in 1982

Industry selling price indexes, 1971 = 100	Annual average										Annual change	
	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1981-82	1972-82
All manufacturing industries	288.7	272.2	247.2	217.8	190.4	174.3	161.6	153.7	138.1	116.1	6%	11%
Chemicals and chemical products	306.8	286.2	251.6	214.8	189.3	175.9	167.2	160.3	137.1	106.5	7	12
Industrial chemicals—inorganic	337.9	313.9	275.3	234.1	204.1	188.4	179.7	169.5	133.5	107.7	8	12
Acetylene, compressed	324.9	266.3	232.9	213.2	191.2	170.7	163.7	150.6	116.2	102.9	22	14
Caustic soda	450.1	383.8	281.0	240.1	221.4	210.7	195.7	169.5	120.2	107.0	17	16
Chlorine	315.6	274.8	248.4	207.9	189.2	180.5	163.3	144.4	114.1	104.3	15	12
Oxygen, gas, and liquid	224.0	215.6	202.4	191.8	174.6	156.8	152.1	136.0	121.2	108.3	4	7
Industrial chemicals—organic	429.7	410.2	354.7	289.0	249.8	228.1	214.2	201.2	170.0	107.8	5	14
Plastics and synthetic resins	297.7	294.7	274.4	239.7	206.4	193.3	187.4	181.6	156.0	104.2	1	9
Alkyd	208.5	196.5	176.9	158.4	137.5	129.4	131.4	135.1	134.8	109.4	6	10
Phenol formaldehyde	344.6	337.6	332.8	300.9	233.6	232.1	235.6	240.9	214.1	111.4	2	8
Polyethylene	290.3	326.9	315.3	268.9	223.2	220.3	221.6	213.2	166.3	103.2	−11	6
Fertilizers, mixed	295.1	290.5	280.3	229.1	191.0	180.2	176.9	204.0	167.5	117.2	2	10
Drugs	211.7	189.7	169.5	153.1	140.4	131.4	127.0	121.1	109.9	103.5	12	10
Paint and varnish	298.3	280.3	239.8	202.3	183.0	172.8	161.9	153.9	131.9	108.2	5	12
Pigments and dry colors	332.9	304.4	260.0	219.6	189.7	175.3	164.9	153.4	136.0	103.7	9	14
Soaps and cleansing compounds	225.5	209.7	189.1	169.5	151.2	141.1	134.5	132.1	118.0	105.3	7	10

Source: Statistics Canada

CHEMICAL IMPORTS: Recession cuts demand

$ Millions (Canadian)[a]	1982	1981	1980	Change 1981-82
Inorganic chemicals	$ 370	$ 399	$ 343	−7%
Organic chemicals	1019	1090	930	−7
Fertilizers and fertilizer materials	143	157	135	−9
Synthetic and reclaimed rubber	142	160	126	−11
Plastics materials	549	607	537	−10
Plastic film and sheet	208	243	192	−14
Other plastic shapes and forms	137	154	129	−11
Dyes, except dyeing intermediates	63	76	80	−17
Pigments, lakes, and toners	52	65	54	−20
Paints and related products	85	98	86	−13
Other chemical products	817	765	742	7
TOTAL	**$3584**	**$3814**	**$3354**	−6%

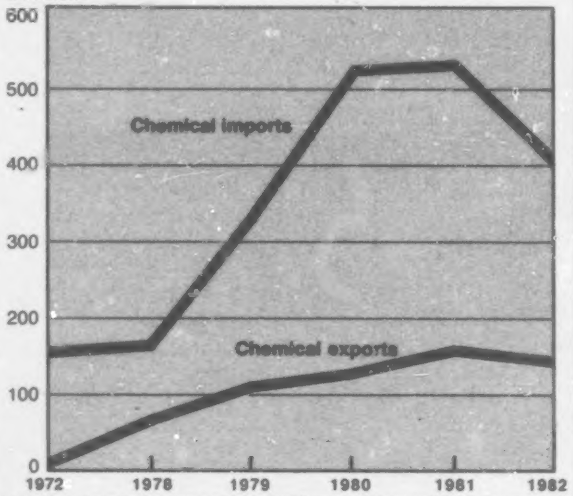
Source: Statistics Canada

CHEMICAL EXPORTS: Big groups slump

$ Millions (Canadian)[a]	1982	1981	1980	Change 1981-82
Chemical elements	$ 170	$ 147	$ 161	16%
Other inorganic chemicals	827	1064	947	−22
Organic chemicals	1099	1183	924	−7
Fertilizers and fertilizer materials	1059	1343	1254	−21
Synthetic rubber and plastic materials	516	513	468	1
Plastics, basic shapes and forms	173	149	124	16
Other chemical products	229	206	178	11
TOTAL	**$4073**	**$4605**	**$4056**	−12%

a Domestic exports only. **Source:** Statistics Canada

Foreign Chemical Industries Mexico 6



Chemical foreign trade shrunk in 1982

Note: Data for trade in primary petrochemicals only; does not include other secondary chemicals. **Source:** Petróleos Mexicanos

PRODUCTION: Gains despite economic slump

Thousands of metric tons[a]	1982	1981	1980	1979	Change 1981–82
Acetaldehyde	149.1	122.2	47.6	48.8	22%
Acrylonitrile	52.7	54.0	54.3	23.3	−2
Ammonia, anhydrous	2469.3	2183.2	1863.2	1652.7	13
Benzene	96.0	76.5	79.3	70.5	25
Butadiene	14.6	12.3	17.0	17.3	19
Cyclohexane	34.9	44.1	39.7	29.2	−21
Cumene	20.4	1.6	0	0	1175
Dichloroethane	201.1	116.9	106.3	97.3	72
Dodecylbenzene	61.8	59.5	55.4	62.8	4
Ethane	1550.3	1337.4	632.2	607.5	16
Ethylbenzene	23.0	29.1	29.3	32.6	−21
Ethylene	395.8	378.3	365.5	342.7	5
Ethylene oxide	79.0	48.5	29.7	24.3	63
Hexane	75.8	65.6	60.1	53.4	16
Hydrochloric acid	46.7	33.2	36.1	31.9	41
Isopropyl alcohol	10.9	15.6	12.6	0.6	−30
Methanol	191.3	179.7	173.6	147.0	6
Nitrogen	39.0	29.5	0	0	32
Oxygen	208.4	159.1	0	0	40
Polyethylene, high density	78.2	78.1	66.9	58.4	0
Polyethylene, low density	93.3	91.2	91.4	95.6	2
Propylene	157.6	156.2	136.9	159.9	1
Propylene tetramer	38.5	35.4	35.8	43.0	9
Styrene	29.0	32.9	31.3	31.2	12
Sulfur, recovered	424.9	425.5	402.4	249.4	0
Toluene	138.1	131.3	124.9	107.9	5
Vinyl chloride	79.4	56.9	62.5	55.7	40
***m*- and *p*-Xylene**	99.2	86.6	77.2	66.0	15
***o*-Xylene**	15.8	16.7	16.1	15.8	−5

a Production of primary petrochemicals by Petróleos Mexicanos (Pemex). **Source:** Pemex

DOMESTIC SALES: Some declines in 1982

Thousands of metric tons[a]	1982	1981	1980	1979	Change 1981–82
Acetaldehyde	156.2	123.7	100.9	58.1	26%
Acrylonitrile	71.4	74.2	67.9	60.1	−4
Ammonia	1338.1	1204.8	966.8	885.7	11
Benzene	12.8	12.2	12 6	11.0	5
Butadiene	66.0	69.5	66.1	57.4	−5
Cyclohexane	50.5	52.6	52.8	52.0	−4
Dodecylbenzene	111.3	92.5	90.1	83.8	20
Ethylene oxide	77.6	77.9	70.5	56.6	0
Hexane	54.2	51.0	46.1	38.9	6
Isopropyl alcohol	47.5	32.4	27.8	21.4	47
Methanol	129.0	125.2	97.8	84.4	3
Perchloroethane	12.7	15.3	13.5	14.6	−17
Polyethylene, high density	120.3	100.1	79.5	63.1	20
Polyethylene, low density	261.3	257.5	224.3	170.4	1
Styrene	117.6	116.9	101.2	99.2	1
Sulfur	365.2	427.5	408.0	243.2	−15
Toluene	86.5	88.4	81.3	76.9	−2
Vinyl chloride	138.7	144.7	148.1	119.8	−4
***o*-Xylene**	26.9	27.0	30.7	28.4	0
***p*-Xylene**	186.9	186.8	116.4	96.7	0

a Domestic sales by Petróleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

CHEMICAL IMPORTS: Many being displaced

Thousands of metric tons[a]	1982	1981	1980	1979	Change 1981–82
Acetaldehyde	12.9	5.9	58.2	10.2	119%
Acrylonitrile	16.8	19.7	8.6	43.0	−15
Benzene	12.2	21.0	14.5	19.9	−42
Butadiene	49.6	55.0	54.8	34.4	−10
Cyclohexane	13.0	7.9	10.1	20.3	65
Dichloroethane	0.0	1.7	14.3	9.0	—
Dodecylbenzene	47.4	32.8	41.3	31.5	45
Ethylbenzene	15.9	10.8	10.0	13.4	47
Ethylene	31.4	15.1	0.0	0.0	108
Ethylene oxide	0.0	31.1	34.4	25.3	—
Isopropyl alcohol	31.1	15.1	18.0	21.7	106
Perchloroethylene	11.3	16.7	5.5	15.1	−32
Polyethylene, high density	17.2	10.2	26.0	5.8	69
Polyethylene, low density	105.7	125.9	104.0	35.9	−16
Propylene	22.1	24.3	20.3	0.2	−9
Propylene tetramer	15.2	23.1	14.5	15.6	−34
Styrene	60.9	87.8	76.7	72.7	−31
Toluene	11.8	22.8	36.7	40.7	−48
Vinyl chloride	70.7	84.3	88.8	62.8	−16
***o*-Xylene**	9.8	12.1	13.3	9.6	−19
***p*-Xylene**	130.6	148.0	94.5	82.3	−12

a Imports by Petróleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

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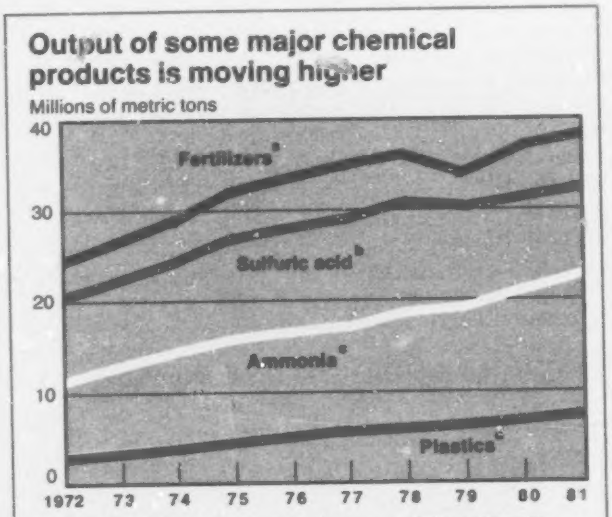
6 Foreign Chemical Industries Eastern Europe

In 1982, industrial output in East Europe and the Soviet Union continued to grow at the slow pace of recent years—up just 2.2% for the region (compared to a goal of 4.2%, and an average rate of 4.8% from 1976 to 1980). Production fell below 1981 growth rates in all seven countries and failed in most nations to meet the modest targets set by national five-year plans. In troubled Poland, production dropped 4%, following a 10.5% decline in 1981. The chemical industries in all the countries showed slower growth in both 1981 and 1982. Output of chemicals and rubber in Czechoslovakia last year actually dropped slightly.


Output of some major chemical products is moving higher

a As N, P_2O_5, and K_2O. b 100% H_2SO_4. c Nitrogen content. d Including resins for man-made fibers in U.S.S.R. **Note:** Data for U.S.S.R., Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania. **Sources:** Central Intelligence Agency, Department of Agriculture, C&EN estimates

MAN-MADE FIBERS: Little change in U.S.S.R.

Production, millions of lb	1982[a]	1981	1980	1979	Change 1981–82
NONCELLULOSIC FIBERS[b]					
Bulgaria	125	114	110	106	10%
Czechoslovakia	251	178	168	159	41
East Germany	315	313	306	292	1
Hungary	44	47	43	40	−6
Poland	283	260	359	338	9
Romania	309	304	300	309	2
U.S.S.R.	1268	1242	1213	1049	2
TOTAL	**2595**	**2458**	**2499**	**2293**	**6%**
CELLULOSIC FIBERS					
Bulgaria	84	81	80	73	4%
Czechoslovakia	121	120	121	148	1
East Germany	358	364	372	364	−2
Hungary	17	16	20	19	6
Poland	142	141	190	185	1
Romania	142	142	140	143	0
U.S.S.R.	1400	1419	1433	1400	−1
TOTAL	**2264**	**2283**	**2356**	**2332**	**−1%**

a Preliminary figures. b Excluding olefins and textile glass. **Source:** Textile Economics Bureau

PRODUCTION GROWTH: Pace continues slow

% annual change in gross output	1982	1981	1980	1979	1978
U.S.S.R. and East Europe					
All industry	2.2%	2.2%	3.4%	3.7%	5.1%
Bulgaria					
All industry	4.6	4.8	4.2	5.5	6.9
Chemicals and rubber	1.3	4.2	11.1	9.1	10.0
Czechoslovakia					
All industry	1.0	2.1	3.5	3.7	5.0
Chemicals and rubber	−0.3	1.7	4.8	3.3	na
East Germany					
All industry[a]	3.2	4.7	4.7	4.6	3.7
Chemicals and rubber	na	3.7	3.3	4.0	6.0
Hungary					
All industry	2.0	2.8	−2.0	3.0	4.9
Chemicals and rubber	1.8	3.1	−2.1	6.1	10.[illegible]
Poland					
All industry	−4.0[b]	−10.5	0.0	2.7	4.9
Chemicals and rubber	na	−1.14	0.4	2.3	3.9
Romania					
All industry	1.1	2.6	6.5	8.1	9.6
Chemicals and rubber	na	3.9	6.6	1.4	10.6
U.S.S.R.					
All industry[c]	2.8	3.4	3.6	3.4	4.8
Chemicals and rubber[c]	3.0	5.5	5.6	2.3	6.0
All industry[d]	na	2.0[e]	2.9	3.0	3.5
Chemicals and rubber[d]	na	3.5[e]	5.2	0.2	3.6

a Industrial commodity production. b Estimated. c Figures based on official Soviet statistics. d Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. e Preliminary figure. na = not available. **Sources:** United Nations Economic Commission for Europe, based on official national statistics, Central Intelligence Agency

AGRICULTURAL CHEMICALS: Fertilizer supply stagnates in Eastern Europe

Thousands of metric tons	1982[a]	1981	1980	1979	1978
Bulgaria					
Fertilizer supply[b]	1,040	1,040	830	820	738
Pesticide supply	na	48.7	40.0	34.8	35.3
Czechoslovakia					
Fertilizer supply[b]	1,722	1,722	1,730	1,745	1,748
East Germany					
Fertilizer supply[b]	1,725	1,725	1,637	1,713	1,670
Pesticide supply	na	27.0	27.0	26.7	25.3
Hungary					
Fertilizer supply[b]	1,542	1,478	1,399	1,502	1,539
Poland					
Fertilizer supply[b]	3,373	3,492	3,635	3,567	3,606
Pesticide supply	na	38.4	29.3	44.4	49.8
Romania					
Fertilizer supply[b]	1,114	1,082	1,185	1,431	1,480
U.S.S.R.					
Fertilizer supply[b]	20,100	19,176	18,763	17,365	18,420
Pesticide supply	na	509	482	na	na

a Preliminary figures. b Nutrient content. na = not available. **Sources:** United Nations Economic Commission for Europe, based on official national statistics; Department of Agriculture

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PRODUCTION: U.S.S.R. accounts for more than two thirds of fertilizers and half of plastics

Thousands of metric tons, unless otherwise noted	1982[a]	1981	1980	1979	1978
U.S.S.R.					
Sulfuric acid, 100%	23,800	24,100	23,033	22,364	22,411
Mineral fertilizers (gross weight)	na	109,106	103,858	94,523	97,976
Mineral fertilizers[b]	26,890	25,998	24,760	22,137	23,653
Nitrogen[b]	11,000	10,705	10,241	9,151	9,299
Phosphate[b,c]	7,010	6,836	6,455	6,344	6,153
Potassium[b]	8,680	8,449	8,064	6,635	8,193
Synthetic ammonia[d]	na	14,650	13,762	12,278	11,462
Sodium carbonate 100%	na	4,900	4,800	4,782	4,858
Plastics[e]	4,100	4,090	3,636	3,478	3,516
Sodium hydroxide, 100%	na	2,757	2,755	2,680	2,763
Synthetic rubber[f]	na	1,860	1,880	1,867	1,795
Rubber tires[g] (thousands of units)	61,700	60,500	60,100	59,981	59,018
Pesticides	533	504	470	475	491
Bulgaria					
Sulfuric acid, 100%	na	920	852	998	974
Mineral fertilizers[b]	999	1,010	947	959	968
Nitrogen[b]	760	753	730	677	685
Phosphate[b]	239	258	217	282	283
Synthetic ammonia[d]	na	1,023	1,009	951	960
Plastics	na	284	254	200	178
Sodium hydroxide, 100%	na	157	161	107	102
Synthetic rubber	na	30	30	30	25
Rubber tires[g] (thousands of units)	na	2,230	2,117	1,793	1,734
CZECHOSLOVAKIA					
Sulfuric acid, 100%	na	1,318	1,284	1,253	1,195
Mineral fertilizers[b]	na	1,085	1,182	1,140	1,176
Nitrogen[b]	na	539	618	591	625
Phosphate[b,c]	na	340	361	358	367
Potassium[b,h]	na	206	203	199	191
Synthetic ammonia[d]	na	na	841	804	812
Plastics	956	913	894	853	810
Sodium hydroxide, 100%	na	331	326	312	311
Synthetic rubber	na	60	60	59	59
Rubber tires[g] (thousands of units)	na	na	6,714	6,581	6,439
EAST GERMANY					
Sulfuric acid, 100%	na	na	958	952	971
Mineral fertilizers[b]	na	4,787	4,735	4,740	4,628
Nitrogen[b]	na	967	943	875	892
Phosphate[b,c]	na	360	370	411	413
Potassium[b]	na	3,460	3,422	3,395	3,323
Synthetic ammonia[d]	na	na	1,159	1,079	1,137
Plastics	na	998	861	779	762
Sodium hydroxide, 100%	na	631	626	548	415
Synthetic rubber	na	175	170	165	145
Rubber tires[g] (thousands of units)	na	7,026	7,067	6,890	6,728
HUNGARY					
Sulfuric acid, 100%	na	600	614	613	690
Mineral fertilizers[b]	na	893	853	850	855
Nitrogen[b]	na	589	559	550	534
Phosphate[b]	na	158	149	165	185
Potassium[b,h]	na	146	145	143	136
Synthetic ammonia[d]	na	na	900	803	746
Plastics	na	311	328	294	213
Sodium hydroxide, 100%[i]	na	180	188	194	146
Rubber tires[g] (thousands of units)	na	870	870	750	773
POLAND					
Sulfuric acid, 100%	na	2,776	3,019	2,983	3,172
Mineral fertilizers[b]	2,283	2,242	2,238	2,431	2,621
Nitrogen[b]	1,297	1,274	1,290	1,376	1,470
Phosphate[b]	868	866	843	931	1,026
Potassium[b,h]	118	103	105	110	125
Synthetic ammonia[d]	na	1,465	1,483	1,530	1,616
Plastics	na	475	549	440	467
Sodium hydroxide, 100%	na	400	415	436	469
Synthetic rubber	na	111	118	130	126
Rubber tires[g] (thousands of units)	na	na	8,743	8,500	7,852
ROMANIA					
Sulfuric acid, 100%	na	na	1,756	1,750	1,655
Mineral fertilizers[b]	2,700	2,640	2,451	2,522	2,461
Nitrogen[b]	na	1,822	1,689	1,738	1,723
Phosphate[b]	na	717	689	709	660
Potassium[b,h]	na	102	73	75	78
Synthetic ammonia[d]	na	na	2,267	2,333	2,259
Plastics	na	580	579	516	552
Sodium hydroxide, 100%	na	na	705	704	725
Synthetic rubber	na	146	150	149	147
Rubber tires[g] (thousands of units)	na	5,250	5,046	4,691	4,690

a Approximate figures. b Nutrient content basis, as N, P_2O_5, or K_2O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g For all motor vehicle tires, excluding aircraft and bicycle tires. h Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. i Including regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, Department of Commerce, Department of Agriculture, United Nations Economic Commission for Europe (based on official national statistics)

SOVIET FOREIGN TRADE: Deficit in chemical trade balance has been widening steadily

$ Millions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Exports[a]	$87,168	$79,380	$76,437	$64,912	$52,435	$45,227	$37,269	$33,407	$27,374	$21,332	$15,409
Imports[a]	77,847	73,157	68,473	57,958	50,798	40,926	38,212	37,070	24,861	20,980	16,104
Trade balance	9,321	6,223	7,964	6,954	1,637	4,301	−943	−3,663	2,513	352	−695
Chemical exports[a]	na	2,398	2,157	1,606	1,264	1,063	939	1,027	887	549	439
Chemical imports[a]	na	4,222	3,861	2,803	2,188	1,850	1,668	1,747	1,448	954	868
Chemical trade balance	na	−1,824	−1,704	−1,197	−904	−787	−729	−720	−561	−405	−429

a Free on board. na = not available. **Sources:** Central Intelligence Agency, Department of Commerce, based on official Soviet statistics and exchange rates

6 Foreign Chemical Industries Western Pacific

KOREA

INDUSTRY TRENDS: Chemical output slips

Index, 1980 = 100	1982	1981	1980	1979	Change 1981-82
Chemicals, petroleum, coal, rubber, and plastic products					
Production	105.9	102.5	100.0	100.3	3%
Shipments	102.4	101.5	100.0	98.6	1
Inventories	117.9	114.8	100.0	72.0	3
Industrial chemicals					
Production	101.5	103.5	100.0	97.0	−2
Shipments	107.8	105.1	100.0	88.9	3
Inventories	120.5	126.6	100.0	75.6	−5
Other chemical products					
Production	122.4	106.1	100.0	108.4	15
Shipments	119.3	106.6	100.0	106.5	12
Inventories	118.5	94.7	100.0	90.9	25
Rubber products					
Production	97.7	98.9	100.0	89.3	−1
Shipments	93.5	94.9	100.0	88.3	−1
Inventories	96.9	107.9	100.0	53.5	−10
Plastic products					
Production	92.6	91.7	100.0	127.9	1
Shipments	92.2	91.2	100.0	124.8	1
Inventories	121.7	96.5	100.0	105.0	26
All manufacturing					
Production	119.2	113.5	100.0	101.9	5
Shipments	116.1	111.3	100.0	99.6	4
Inventories	126.5	110.4	100.0	72.7	15

Source: Korean Bureau of Statistics

FOREIGN TRADE: Deficit narrowed last year

$ Millions	1982	1981	1980	1979
Exports[a]	$21,853	$21,254	$17,505	$15,056
Imports[b]	24,251	26,131	22,292	20,339
Trade balance	−2,398	−4,877	−4,787	−5,283
Chemical exports	731	682	780	532
Chemical imports	2,080	2,109	1,836	2,009
Chemical trade balance	−1,349	−1,427	−1,055	−1,477

a Free on board. b Includes cost, insurance, freight. **Source:** Korean Bureau of Statistics

PRODUCTION: Nitrogen fertilizers decline

Thousands of metric tons	1982	1981	1980	1979	Change 1981-1982
Sulfuric acid	1596	1304	1702	1645	22%
Complex fertilizers	1667	1211	1439	1696	38
Ammonia	661	908	1031	1169	−27
Urea fertilizers	788	1070	973	1166	−26
Ethylene	374	374	368	na	0
Polyvinyl chloride	312[a]	287	232	192	9
Sodium carbonate	186[a]	202	222	204	−8
Insecticides	58	54	75	101	7
Synthetic detergents	52	57	64	70	−8

a Preliminary value. na = not available. **Source:** Korean Bureau of Statistics

AUSTRALIA

PRODUCTION: Little change in past few years

Thousands of metric tons	1982[a]	1981[a]	1980[a]	1979[a]	Change 1981-82
Chemicals and acids					
Hydrochloric acid, 100%	55	59	63	58	−7%
Nitric acid, 100%	180	182	180	169	−1
Sulfuric acid, 100%	2027	1963	2175	1922	3
Ammonium sulfate	207	211	203	212	−2
Superphosphate[b]	3568	3770	4202	3646	−5
Plastics and resins	799	806	796	614	−1
Synthetic detergents	205	199	202	185	3
Unsupported plastics film, sheeting	118	125	130	118	−6
Polyethylene[c]	82	84	89	77	[illegible]
Polyvinyl chloride[d]	20	18	17	16	11

a Years ending June 30. b Includes double and triple superphosphates and ammonium phosphate expressed in terms of single phosphate (22% P_2O_5 equivalent). c Low and high density. d Including copolymers. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Overall balance unfavorable

$ Millions	1982[a]	1981[a]	1980[a]	1979[a]
Exports[b,c]	$20,946	$22,314	$21,079	$16,219
Imports[d]	24,617	22,068	18,116	15,662
Trade balance	−3,671	246	2,963	557
Chemical exports[b,c]	430	487	424	351
Medicinal products	95	95	78	74
Chemical imports[d]	1,955	1,842	1,764	1,368
Organic chemicals	530	509	543	371
Chemical trade balance	−1,525	−1,355	−1,340	−1,017

a Years ending June 30. b Free on board. c Includes re-exports. d Values for customs purposes, free-on-board basis. **Source:** Australian Bureau of Statisti[illegible]

CHINA

PRODUCTION: Growth last year generally was stronger than in 1981

Thousands of metric tons	1982	1981	1980	1979	Change 1981–82
Ammonia[a]	na	11,990	12,150	10,727	na
Fertilizer[b]	12,781	12,390	12,320	10,654	3%
Nitrogen (N)	10,219	9,860	9,990	8,821	4
Phosphate (P_2O_5)[c]	2,537	2,510	2,310	1,817	1
Potash (K_2O)	25	20	20	16	25
Sulfuric acid	8,170	7,810	7,640	7,000	5
Sodium hydroxide	2,073	1,923	1,923	1,826	8
Sodium carbonate	1,735	1,652	1,613	1,486	5

Thousands of metric tons	1982	1981	1980	1979	Change 1981–82
Calcium carbide	1,670	1,510	1,520	1,407	10%
Plastics	1,003	916	898	793	9
Insecticides	457	484	537	537	−6
Ethylene	560	500	490	435	12
Synthetic detergents	569	478	393	397	19
Man-made fibers	517	527	450	326	−2
Pharmaceuticals	42	37	40	42	13

a Nitrogen content of ammonia produced for fertilizer. b Nutrient content. c Including production of ground phosphate rock for direct application and phosphate animal feeds. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, Central Intelligence Agency

CHEMICAL IMPORTS: Down in 1981

$ Millions[a]	1981	1980	1979	Change 1980–81
Fertilizers[b]	$ 807	$ 978	$ 609	−17%
Nitrogenous fertilizer	500	674	511	−26
Chemical elements and compounds	477	542	405	−12
Organic chemicals	381	391	255	−3
Plastic materials, resins	471	372	156	27
Dyeing, tanning, and coloring materials	109	80	88	36
Medicinal products	28	19	13	47
Essential oils, perfume, and cleansing materials	16	9	10	78
Other chemicals[c]	157	182	165	−14
TOTAL	**$2066**	**$2182**	**$1446**	**−5%**

a Free on board. b Manufactured. c Includes explosives and pyrotechnic products; mineral tar and crude chemicals from coal, oil, and natural gas; and chemical materials and products not elsewhere specified. **Source:** Central Intelligence Agency, estimated from data reported by China's trade partners

CHEMICAL EXPORTS: Uptrend continues

$ Millions[a]	1981	1980	1979	Change 1980–81
Chemical elements and compounds	$ 554	$ 478	$273	16%
Organic chemicals	297	275	165	8
Medicinal products	190	184	113	3
Essential oils, perfume, and cleansing materials	91	98	78	−7
Explosives and pyrotechnic products	93	94	72	−1
Plastic materials, resins	61	73	48	−16
Dyeing, tanning, and coloring materials	63	58	44	9
Mineral tar and crude chemicals[b]	56	27	9	107
Fertilizers[c]	5	4	2	25
Other chemical products	189	165	124	15
TOTAL	**$1300**	**$1182**	**$763**	**10%**

a Free on board. b From coal, oil, and natural gas. c Manufactured. **Source:** Central Intelligence Agency, estimated from data reported by China's trade partners

TAIWAN

INDUSTRY TRENDS: Industrial chemicals down

Industrial production indexes, 1976 = 100	1982	1981	1980	1979	Change 1981–82
All manufacturing	172.4	169.3	163.2	153.0	2%
Chemical materials	208.2	205.1	201.2	189.1	2
Basic chemicals	131.7	152.5	150.2	148.5	−14
Petrochemicals	239.6	262.3	254.4	242.0	−9
Fertilizers	86.9	124.0	134.6	127.9	−30
Synthetic fibers	214.9	197.4	187.7	174.5	9
Plastics and resins	247.5	210.4	214.5	197.5	18
Chemical products	207.6	176.7	163.9	161.0	17

Source: Council for Economic Planning & Development, Taiwan

FOREIGN TRADE: Chemical deficit narrows

$ Millions	1982	1981	1980	1979
Exports[a]	$22,204	$22,611	$19,811	$16,103
Imports[b]	18,888	21,200	19,733	14,774
Trade balance	3,316	1,411	78	1,330
Chemical exports[a,c]	1,012	973	494	356
Chemical imports[b,c]	2,311	2,704	2,024	1,817
Chemical trade balance	−1,299	−1,731	−1,530	−1,461

a Free on board. b Includes cost, insurance, and freight. c Includes chemicals, chemical products, pharmaceuticals, chemical fertilizers, plastic materials, and synthetic resins. **Sources:** Council for Economic Planning & Development, Taiwan, C&EN estimates

PRODUCTION: Off sharply for several chemicals

Thousands of metric tons, unless otherwise noted	1982	1981	1980	1979	Change 1981–82
Fertilizers[a]	na	1921	2092	1979	na
Man-made fibers	730	687	633	587	6%
Polyvinyl chloride	459	456	454	407	1
Synthetic detergents	95	94	104	105	1
Benzene[b]	130	137	145	153	−5
Ethylene	452	443	458	445	2
Ethylene glycol	120	156	133	118	−23
Propylene	225	204	213	205	10
Toluene[b]	113	172	153	134	−34
Vinyl chloride	434	411	405	317	6
Xylene[b]	230	277	311	285	−17
Ammonia, anhydrous	386	494	504	476	−22
Ammonium sulfate	373	504	539	556	−26
Calcium superphosphate	160	226	207	208	−29
Hydrochloric acid	191	184	179	180	4
Oxygen[c]	156	174	159	141	−10
Sodium hydroxide	355	373	411	430	−5
Sulfuric acid	685	819	769	777	−16
Urea	175	285	343	312	−39

a In terms of 20% N, 18% P_2O_5, and 50% K_2O fertilizer. b Millions of liters. c Millions of cubic meters. na = not available. **Source:** Council for Economic Planning & Development, Taiwan

JUNE 20, 1983

CHEMICAL & ENGINEERING NEWS

Scientists explain rationale behind major new nuclear arms initiatives
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Plastics monomers enjoy brisk recovery

A Key Chemicals Review Page 16

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Cover: PPG Industries' vinyl chloride plant,
Lake Charles, La.

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CHEMICAL & ENGINEERING NEWS

JUNE 20, 1983

News of the Week

- **Nerve-gas weapon production ban will continue as result of House vote to cut binary chemical arms funds from Department of Defense's procurement bill.** **Page 4**
- **Four scientists win General Motors awards for their contributions to cancer research.** **Page 5**
- **EPA's Ruckelshaus urges an extension of the Clean Water Act compliance deadline past July 1, 1984.** **Page 5**

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Business

Vinyl chloride, styrene, and toluene diisocyanate use is rolling upward in the best market situation since 1979. **Page 16**

International

Global methanol capacity will exceed demand 29% by 1985; overly optimistic projections for use in fuel to blame. **Page 20**

Petrochemicals in Canada and the U.K. suffer from overcapacity, leaving both countries looking for new markets. **Page 22**

Government

Acid rain tie to man-made pollution acknowledged in government's first annual report on national acid rain program. **Page 27**

House is acting quickly in passing bills setting research funding levels; Department of Defense has initiated a grant program for instrumentation research. **Page 29**

Science

DNA's genetic code as a late development in molecular evolution gains credence, reversing the conventional view. **Page 33**

Education

Fewer than half the chemical engineers graduating with bachelors degrees in 1983 have jobs or grad schools waiting. **Page 35**

Technology

New family of aluminophosphate molecular sieves has increased the types of shape-selective catalysts and adsorbents. **Page 36**

News Focus

Scientists George Keyworth and John Deutch offer an inside look at the Reagan Administration's nuclear arms policies. **Page 6**

Plastics Intermediates Are Rebounding Strongly

To producers' surprise, vinyl chloride, styrene, and toluene diisocyanate use is growing fast; rate could slow a bit later in year

Bruce F. Greek, C&EN Houston

This year as usual, business forecasts have been wrong about plastics intermediates, but this time the error is a happy one. Instead of slowly struggling out of the recessionary quagmire from 1982, plastics starting materials such as the three in the following pages—vinyl chloride, styrene, and toluene diisocyanate (TDI)—are rolling toward mid-1983 at an impressive clip. Although producers figure the current rate very likely could throttle back in late 1983 and 1984, they are still pleased at their best market situation since 1979.

There's some variation in the fortunes of these chemicals. One, TDI, appears close to a supply crunch in its polyurethane market that could last two years or more. Vinyl chloride and styrene have plenty of surplus capacity still, though at higher prices, so they could handle demand growth through 1984 and beyond.

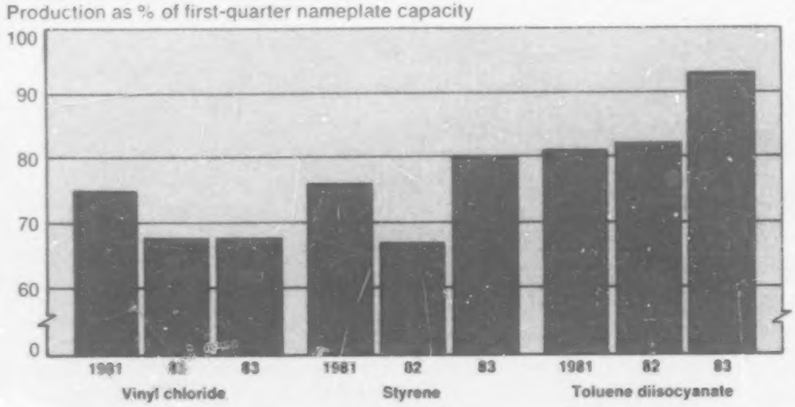
All producers of these intermediates have responded as expected to the strong upsurge in demand—they have raised prices. They probably will raise them even more later this year, partly to continue the new profitability gains, but also to pass on cost increases, some that producers had to absorb in the dismal days of 1982.

Key Chemicals

The higher tags, often in the form of reduced or rescinded discounts, will push up estimated combined 1983 value for these three chemicals nearly $400 million or 18% to $3.9 billion.

Combined production will rise considerably less. Estimates taking into account a slowing growth rate later in the year total a bit more than 14 billion lb, up 8% from 1982.

Plant use up sharply in styrene, toluene diisocyanate



Sources: International Trade Commission, industry and C&EN estimates

Although hardly displeased with their newly revalued chemicals, producers are still a bit nervous about the current business pace. The production pipeline from chemicals to plastics to end markets has a strong enough momentum now to get producers into trouble if demand in important areas such as housing and autos takes any sudden turn.

Although no radical declines in housing or auto sales are expected later in 1983 or in 1984, the current upswing could yield to a leveling off. If something like this happens, producers worry that inventories may start to look too big in view of their carrying costs. This would lead to some trimming and a marked effect on growth rates in the intermediates. Part of the current problem is that the coming summer months, seasonally slower than the spring, could mask the real situation and fool producers up and down the market chain into believing that the first-half clip will continue after a slight hot-weather pause.

So the fourth quarter of 1983 looms as an important test for the whole U.S. economic recovery and certainly for plastics materials' role in it. Questions involved will include the wisdom of closing more old capacity in vinyl chloride and styrene, the need to schedule construction of new capacity, and the always tricky matter of end-of-the-year tax adjustments in inventories.

For now, many industry voices hope that the new business wave won't boomerang in an overdone sequence of inventory building, capacity expansion, and then painful adjustments in a cooled-off economy. First-half 1983 has been good to plastics materials people, and they want to keep it that way.

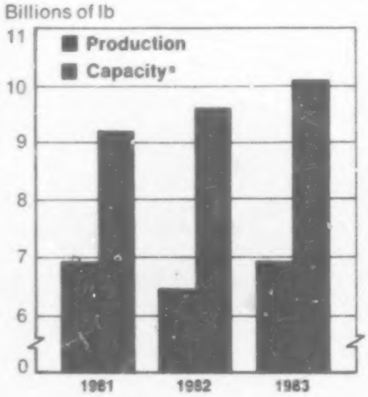
Key Polymers

$CH_2{=}CHCl$

Vinyl Chloride

- ***Demand rebounding***
- ***Capacity due down***
- ***Prices going up***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Dehydrochlorination of ethylene dichloride made by reacting chlorine with ethylene

MAJOR DERIVATIVES (U.S.)

Vinyl polymers nearly 100%

MAJOR END USES (U.S.)

Fabricated plastic items nearly 100%

FOREIGN TRADE

Exports—may decline in 1983 to about 800 million lb, imports—less than 100 million lb

PRICES

List price 22 cents per lb and scheduled to rise

COMMERCIAL VALUE

$1.3 billion for production, 1983

After suffering more than U.S. producers thought possible in last year's recession, vinyl chloride is doing better in 1983. Producers are considerably buoyed by the prospects. One sure sign is their attempt at the moment to raise list prices after enduring discounts of one third or more 12 months ago.

Production this year has a shot at the old record of 6.9 billion lb in 1981 and 1978. One expert who thinks a new sales peak could be in view points out that production went up substantially in the first quarter and demand prospects are still improving.

But vinyl chloride does have some problems—not considered serious by optimists but thought a potential drag by pessimists. One of the top concerns is a "cost push" from behind. Raw material chlorine producers are agitating for a big price increase at the moment, under pressure from falling markets for chlorine's coproduct, caustic soda. Chlorine price increases already have been widespread and may continue later this year. These reflect costs of chlorine's electrochemical production units, which continued to rise as energy and other costs rose even in the recession. Because vinyl chloride's molecular weight is more than half chlorine, a price increase for chlorine quickly turns into price increases for vinyl chloride.

Currently, list prices for vinyl chloride run 22 cents a lb, but there's an effort under way to raise them to 25 cents a lb. Heavy temporary voluntary allowances (official discounts) a year ago had prices down as much as 14 cents. Currently, discounting continues from the 22-cent level but not nearly as much as in 1982.

Vinyl chloride's other raw material, ethylene, also had a price hike this spring, though not as much. Ethylene prices are scheduled to go up again, perhaps as much as 10% in the third quarter. This coming boost, coupled with the recent chlorine price action, is behind the price push in vinyl chloride. Another one could be due later in 1983 as producers continue to pass on cost increases.

In the face of these cost increases, vinyl chloride producers may have a suspenseful time on profitability this year. Presumably, in raising their own prices, producers are including something for themselves in addition to passing along cost increases. But the market may have something to say about how much of a price increase makes it before demand growth starts to flag.

Even with such a potential damper, the mid-range outlook for 1983 vinyl chloride production is for a 6% increase from 1982 production of 6.5 billion lb. The range of production estimates isn't as broad as for some other major organic chemicals, going from a low of 6.7 billion lb (3% gain) to a high of 7.1 billion lb (8% gain).

Vinyl chloride's plant operating rates also are headed up, in fact, faster than production. The major reason is permanent shutdown of Shell's vinyl chloride unit at Norco, La., taking away 700 million lb of capacity. Slightly offsetting this will be 300 million lb of added capacity later this year at Du Pont (Conoco) at Lake Charles, La. So for the year, available (although not necessarily operting) nameplate capacity appears to balance out at about 9.5 billion lb. The operating rate on this basis will be more than 72%. However, more realistically, the effective operating rate will hit 80% or more, given temporary plant shutdowns and vinyl chloride's somewhat lower than average effective top operating rate.

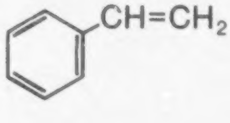
Powering the use rate increase will be a hefty U.S. market rebound. Demand in the U.S. will increase more than will production because exports are forecast to fall 100 million lb or so from more than 900 million lb in 1982.

Demand for polyvinyl chloride, which accounts for practically all vinyl chloride use, is rising on the strength of the general economic recovery, especially in housing (C&EN, April 18, page 11). About the only concern is potential trouble from overdone inventory building of fabricated PVC products such as pipe and fittings. If inventories get out of hand and interest rates continue to creep up, inventory cutting in 1984 could hurt further growth for vinyl chloride.

For 1983, however, vinyl chloride producers seem likely to have a much improved year over 1982 in both demand and profitability. And these important marketing factors are unlikely to spur a round of capacity additions for at least two more years.

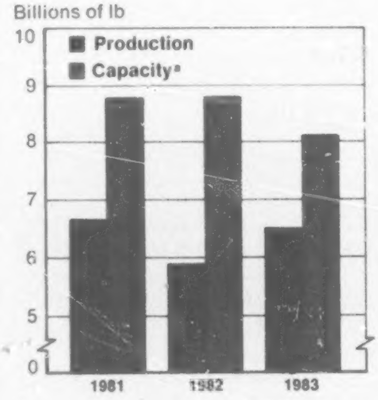
Key Polymers

Styrene



- ***Demand recovering***
- ***Capacity down***
- ***Prices firming***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Dehydrogenation of ethylbenzene, made either from ethylene and benzene or recovered from petroleum reformate; coproduction with propylene oxide

MAJOR DERIVATIVES (U.S.)

Plastics-oriented polymers 85%, styrene-butadiene rubber 10%

FOREIGN TRADE

Exports—may rise 5% in 1983 to more than 1 billion lb, imports—25 million to 50 million lb

PRICES

List prices 32 to 36 cents per lb

COMMERCIAL VALUE

$2 billion for production, 1983

Styrene looked for a while like a laggard in the current U.S. economic recovery. But then spring come along, and styrene took off. It now seems to be making up for lost time, with demand strong and prices firming again for the beginning of the third quarter.

The jump in reported production in March was spectacular. Including some estimated data, the U.S. International Trade Commission puts March production at 578 million lb, up more than 140 million lb from February. Even allowing 10% more production for the longer month, the rise in March was greater than expected.

Some slumping then occurred in April, sources say, but May output apparently again came on strong. By this time, styrene's recovery had become clear and prices firmed, spurred partly by increases in raw material benzene prices. Current list prices have reached 32 cents a lb minimum through elimination of temporary voluntary allowances (official discounts) Actual selling prices have gone up even more than list prices, so discounts are shrinking fast.

Discounting in styrene's price might become negligible in the third quarter, according to some optimists. Supplies are widely reported as becoming tighter, and there are plans for plant shutdowns for maintenance this summer.

Still, styrene is in no danger of shortage. Although capacity has decreased because older, inefficient plants were shut down during the recession, plenty of capacity remains if it is operated. And no real tightness in supplies of raw material benzene or ethylene will occur for quite some time.

As 1983 began, operable styrene capacity exceeded 8 billion lb per year. Not all of it was operating at the time, but all is expected to be running for the second half of the year. No additional capacity, except for possible debottlenecking, will become available in 1983. In fact, major expansion could be some time off. Even if planning firmed up now, the earliest on-stream dates for new capacity would be toward the end of 1985 or in 1986.

Opinion varies a lot on 1983 styrene production. Pessimists cite the first-quarter output of 1.4 billion lb as a drag for the year and call for an overall gain of just 5% to 6.2 billion lb from 1982. Optimists, however, look at the robust March figure and believe that things will be even better in the second half. They call for a 1983 total of 7 billion lb. Average opinion now looks for a 10% gain to about 6.5 billion lb.

If production hits this level, plants will operate at an average rate of 80%. Clearly, capacity will not be strained even if temporary shutdowns take out another two to four weeks of production.

Still, breaking the 80% level certainly will help this business, badly depressed until recently. A production upturn in 1983 would be the first in four years since the previous high in 1979 of 7.5 billion lb.

Styrene's production pickup is the result of a combination of demand gains in all major use segments and of some inventory building. The major end use, polymers (mainly polystyrene), probably will not show a full 10% gain for 1983 but could surprise producers with end-of-the year strength, some analysts think.

At present, inventories of styrenic polymers are moving up, helping increase demand for styrene. Use of the co- and terpolymers, such as acrylonitrile-butadiene-styrene, might gain more than 10% because of their relatively smaller size and greater damage in the recession.

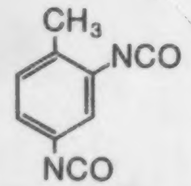
Styrene-butadiene rubber and latexes also have shown signs of a strong recovery. Here, auto production and replacement tire sales are helping more than expected earlier in the year. Carpet-backing use of these polymers is also picking up as a result of the upswing in home building.

By contrast, exports of styrene might be in for their last gala time in 1983 with a rise to as much as 1.15 billion lb. Of course, a looming loss of exports has been forecast before, because of new foreign plants, but it's anybody's guess whether 1984 will be the beginning. For 1983, export strength in volume and in prices still will help U.S. styrene producers.

So styrene will get market help across the board this year, in the U.S. and abroad. That can't yet make the year another 1979, but at least styrene is beginning to make money again.

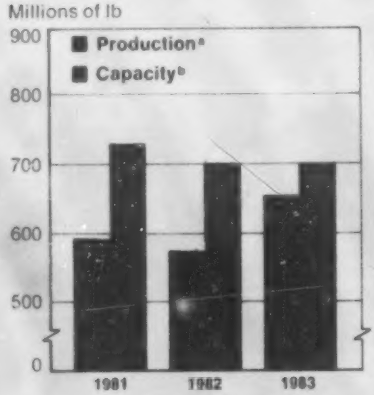
Key Polymers

Toluene Diisocyanate



- ***Demand up strongly***
- ***Capacity flat***
- ***Prices firm***

PRODUCTION/CAPACITY



a Mainly 80/20% mixtures of 2,4- and 2,6-isomers. b First quarter.

HOW MADE

Nitration of toluene, followed by reduction to diamine, reaction with phosgene, purification, and recovery of coproduct hydrochloric acid

MAJOR DERIVATIVES (U.S.)

Polyurethanes almost 100%

MAJOR ENDS USES (U.S.)

Flexible polyurethane foams 90%, polyurethane coatings 5%

FOREIGN TRADE

Exports—to hold around 190 million lb in 1983, imports—negligible

PRICES

List price 93 cents per lb

COMMERCIAL VALUE

$600 million for production, 1983

Toluene diisocyanate producers are sitting pretty. They had one of the easiest passages in the U.S. chemical industry in last year's recession, and this year, supply of their product is already getting tight. Although TDI is somewhat of a statistical fugitive—data on both production and capacity aren't considered very exact—it's apparent that plant use is quite high.

Recovery from the recession started early, beginning in late 1982. Production began to turn up, and prices soon followed. Production in 1982 fell slightly from 1981, according to estimates by the U.S. International Trade Commission. However, other estimates from the Society of the Plastics Industry, slightly lower, put production for both years about the same.

For 1983, early estimates of first-quarter production are up substantially as are estimates for end-use polyurethanes. Although the first-quarter rates likely won't be maintained for the year, analysts still put TDI's 1983 production up 10 to 15% over 1982 to perhaps 650 million lb. This volume is about the maximum possible from nameplate capacity of about 700 million lb a year. Usually, effective top capacity in TDI runs below that of most other major organic chemicals as a percentage of nameplate because of the complexity of the several processing and purification steps.

The ITC estimate of TDI first-quarter production was up more than 14% over first-quarter 1982, suggesting that U.S. capacity was running just about all out. If 1983 production does total 650 million lb, capacity will have to run at an average of nearly 93% of the nameplate total—very high for TDI. No additions to capacity will be coming this year except for some possible small gains through plant debottlenecking. So producers could be faced with a year-long scramble to meet demand—a situation not faced by any major segment of the chemical industry in a long time.

Part of the reason for the high operating rate in the first quarter came from producers' plans to end discounts from the list price of 93 cents a lb for the standard 80/20% mixture of TDI isomers. Major consumers of TDI—makers of polyurethane foams—also saw recovery coming for their products. So inventory building began in at least two levels of the consumption chain, with the objective of improving future profitability by beating a TDI selling price increase.

This inventory building program could be an asset later in 1983 when the full impact hits from the big increase in housing starts. When buyers of new homes start moving in, they will be looking for furniture, which consumes 40% of flexible polyurethane foams, the type made from TDI. Presumably, all of the foam needed by furniture markets will be available.

The same assumption applies to the second largest flexible foam outlet, autos. Although auto production has not yet recovered as well as some industry observers forecast, a somewhat wider use of polyurethane foams in autos and the pickup in large-sized car sales add up to an upswing in polyurethane demand.

Bedding, the third largest use of flexible foams, also will cash in on the housing recovery. It and other housing uses such as carpet backings and underlays likely will increase strongly and will further press TDI capacity limits.

The small TDI uses such as coatings and elastomers also will participate in the economic recovery and push up demand. However, these uses are so minor that even relatively big gains will not affect TDI demand much.

TDI's booming export business this year is expected to at least match the 1982 level of about 190 million lb, barring a capacity squeeze. One caveat is the strong dollar, which could make exports less desirable to customers abroad than at home. However, if as expected the economies of the rest of the world improve following improvement in the U.S., demand could push up export prices just the same. If not, U.S. consumers might get a tad of relief in supply and price pressure.

In other words, TDI has its best year in store in a long time. The shakeout it went through in producers and capacity at the turn of the decade is now having a highly beneficial effect on this business. Producers have kept their restraint on capacity expansion and simply waited for better days. That kind of patience has now paid off, thanks to some nice surprises in leading markets.

Global Methanol Overcapacity Will Get Worse

Capacity will exceed demand by 21% in 1983 and widen to 29% by 1985, primarily because fuel markets haven't developed as expected

Earl V. Anderson, C&EN New York

The world methanol situation is going to get worse before it gets better. World capacity, which this year exceeds demand by 21%, will rise to 29% above world demand by 1985.

After that, capacity relative to demand will get better—but not much better. Surplus capacity will shrink, but still will hover around 21% above world demand. That will put methanol producers right back to where they are now.

That's how A. E. "Sam" Egglestone, senior vice president of Alberta Gas Chemicals Ltd., sees the world methanol picture developing over the next five years. "It's not a pretty picture," Egglestone said at a meeting of the Chemical Institute of Canada (CIC) in Calgary, Alta.

It is particularly not pretty for Canada. Three companies—Alberta Gas Chemicals, Celanese Canada, and Ocelot Industries—have worldscale methanol plants in Canada with a combined capacity of 1.8 million metric tons per year. That's more than a four-fold increase since 1980. And Canadian demand, which will rise from 230,000 metric tons this year to 340,000 metric tons by 1988, pales by comparison. Obviously, says Egglestone, Canadian methanol producers have to export. But they will have to do it into a head wind of worldwide oversupply.

Egglestone lays the blame for the bind that methanol producers are in squarely on overly optimistic projections on methanol's use in fuel. The recession no doubt has had an impact on methanol's misfortunes, but not nearly so much as fuel markets not developing as expected.

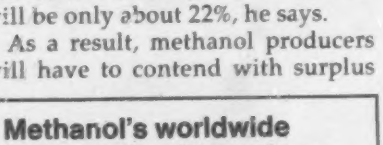
During past oil crises, fuel methanol was seen as one of the best solutions to the energy problem. Market researchers, confident that fuel was a market for methanol whose time had come, turned out glowingly optimistic reports.

Companies, especially those in areas with low-cost natural gas such as Canada and the Middle East, jumped on the methanol bandwagon. Even if the fuel market didn't catch on, they felt that their low-cost feedstock base would enable them to capture a share of traditional methanol markets.

Instead, Egglestone estimates that fuel uses will account for no more than 10% of world methanol consumption this year. Even by 1988, fuel's share of the methanol market will be only about 22%, he says.

As a result, methanol producers will have to contend with surplus capacity for some time. To make matters worse for Canadian producers, the most serious methanol supply-demand imbalance is in North America—that is, the U.S., Canada, and Mexico. This area will account for 88% of the world methanol surplus this year. And, although the North American situation will improve, the region still will have more than half of the world surplus in 1985 and more than a third in 1988.

Methanol's worldwide oversupply will continue



Source: Alberta Gas Chemicals

The two other areas that will have huge overcapacities in methanol are East Europe, where the Soviet Union is emerging as a major supplier, and the Africa-Middle East region, particularly Saudi Arabia.

Fortunately for methanol producers, there are some areas that are or will have short supplies of methanol. Right now, the Pacific Basin and Southeast Asia are the biggest deficit areas. The methanol shortage there will shrink, however, as new units are brought on stream in southeast Asian countries.

Western Europe, already short on methanol, will emerge with the largest shortfall by 1988. And the U.S., which now has substantial overcapacity in methanol, will require some imported material by 1988, says Egglestone.

These developments indicate how methanol trade patterns will change over the next few years. The methanol-rich areas will be fighting for markets in the methanol-poor regions. Unfortunately, it will be a case of too many horses maneuvering for too few stalls.

This will put a lot of pressure on Canadian producers. Even without the huge 2 million-metric-ton plant proposed by Biewag Energy Resources (which Egglestone doesn't think will be built), the industry can never expect Canadian demand to soak up available supply.

To the south, the U.S. now has a 1.2 million-metric-ton surplus. But Egglestone expects that the U.S. will require 380,000 metric tons of imports by 1988.

Still, that's a small target for a country that will have 1.5 million metric tons more methanol than it will need in 1988. Besides, Canadian producers may have to contend with competition from Mexico, if that country is able to get its economic act back together.

Western Europe will be the most attractive target for methanol exporters. Based on existing supply-demand estimates, Western Europe already is about 310,000 metric tons short on methanol. This shortage will soar to 1.3 million metric tons by 1988, says Egglestone.

However, both Eastern Europe producers and producers in Africa and the Middle East will be strong contenders to make up the western European shortfall. Canadian producers will be hard-pressed to meet this competition.

In East Europe, the Soviet Union is emerging as the dominant methanol supplier. Two new plants, at Gubaha and Tomsk, each with a capacity of 2500 metric tons per day, will push Soviet capacity up from 1.9 million metric tons this year to 3.55 million metric tons in 1988. Other huge increases are slated for East Germany and Yugoslavia.

In Africa and the Middle East, Saudi Arabia has two, 2000 metric-ton-per-day units planned that will double capacity to 1.2 million metric tons per year. The United Arab Emirates, Libya, and Bahrain also will become big methanol producers.

Excluding Mexico, which will have more methanol than it will know what to do with, Latin American supply and demand will be virtually in balance. This, then, leaves the Pacific Basin and Southeast Asia as major outlets for Canadian methanol.

Japan now is the major methanol producer in the region. But Japanese producers can't compete with the new, low-cost lineup. They are shutting down plants and will rely increasingly on imports.

However, new capacity will be built in other parts of the region. A new, 1200 metric-ton-per-day plant, half owned by Alberta Gas, will be on stream this year. By 1988, additional capacity should be on stream in Indonesia, Malaysia, and Burma. There are some doubts, however, about the Indonesian plant.

Canada's methanol supply far exceeds demand

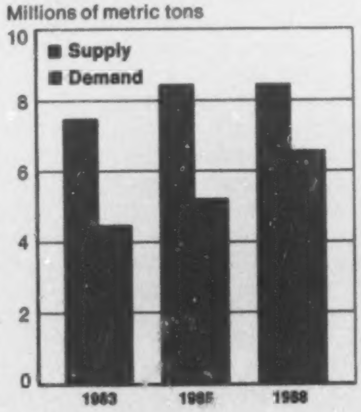
Thousands of metric tons	1983	1985	1988
Effective supply[a]	1810	1810	1810[b]
Alberta Gas Chemicals	720	720	720
Celanese Canada	690	690	690
Ocelot Industries	400	400	400
Domestic demand	230	255	340
Surplus	1580	1555	1470

a Estimated at daily capacity X 330. b Does not include proposed Biewag plant. Source: Alberta Gas Chemicals

Still, the Pacific Basin-Southeast Asia region will become more self-sufficient in methanol over the next five years. Egglestone sees the region's deficit falling from 700,000 metric tons to only 110,000 metric tons by 1988. This, too, is a small target for methanol-rich exporters, and Canadian producers will face strong competition for the market from the Middle East.

What would help Canadian methanol producers—indeed, all producers—is for the fuel market to develop as anticipated a few years ago. But how it will, in fact, develop is anybody's guess, says Egglestone.

Methanol glut in North America will persist



Source: Alberta Gas Chemicals

Certainly fuel methanol—that is, low-level blends of up to 5% methanol in gasoline, high-level blends of up to 12%, and "neat" methanol containing 85% or more—has its advantages. More than 2 barrels of crude are backed out of fuel demand for every barrel of methane used. A 5% methanol-gasoline blend increases road octane by two points. This can be significant for countries facing lead phasedown. Egglestone says that methanol fuel demand likely will be helped next month when the U.S. goes to 1.1 g per gal of lead.

However, fuel methanol has many problems, most of which are solvable but which are holding up methanol fuel development nonetheless. One major problem is that cosolvent alcohols—C-3s and C-4s—must be used with methanol blends. These alcohols sell for about $2.00 per gal, whereas methanol is about 50 cents, according to Egglestone. Thus, economics are a problem. And, he adds, the limited availability of these cosolvent alcohols places an upper limit in the amount of methanol that can be used in fuel. And, of course, today's relatively low crude oil prices aren't helping methanol's cause much.

Still, the outlook for methanol in fuel could change abruptly, says Egglestone. An increase in crude prices could put methanol fuel in a better light. Incentives, such as the tax breaks given to methanol fuel by several states in the U.S., also could help. In Canada, prospects for such incentives "are just about zero," says Egglestone.

He suggests that the best way to go may be to convert methanol directly into gasoline, rather than blend it in. Everyone is watching New Zealand, where a 4400 metric-ton-per-day unit is dedicated to gasoline using the Mobil process.

Egglestone points out that the biggest energy penalty in the methanol-to-gasoline process is in producing methanol from natural gas. The methanol-to-gasoline step is less energy intensive. Because this approach avoids many of the problems associated with methanol fuel blends, the smaller additional energy penalty may be worth paying, he says.

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JUNE 27, 1983

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A1250-1

Health care benefits caught in a squeeze

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News Focus

Health care costs are soaring, and chemical companies are joining other corporations in finding ways to reduce medical benefits to employees. Page 6

Chemical Firms' Health Care Plans Getting Face Lift

With the cost of health care soaring, chemical companies are instituting medical benefits programs that often require employees to carry more of the financial burden

David Webber, C&EN New York

"Starting May 1, 1983, a smarter . . . more cost-conscious program." So salaried employees of B. F. Goodrich read on the cover of a glossy brochure mailed them earlier this year. Inside they learned that Goodrich, which says its health care costs have more than tripled in the past 10 years, was changing its health care plan.

No longer would the company cover medical expenses from the first dollar on. Instead, employees, through deductibles and other measures, would pay a larger share. "The new program will help us reshape our attitudes about using health care services in the future," the brochure went on to say. "This new awareness will cause us to become smarter, more cost-conscious health care consumers."

Messages like this have gone out to employees of chemical companies and other corporations with increasing frequency over the past year. Probably more than half of the biggest companies nationwide have reacted to rapidly rising health care costs by altering their medical benefits plans to make employees share more of the cost. And many more firms are actively considering doing so.

What is happening is nothing less than a major reversal in a corporate current that has been moving in one direction for the past quarter century. Health care plans, which have steadily broadened in scope and have long been considered one of the most sacrosanct of corporate fringe benefits, are now the primary target of a broad corporate assault on costs. A watershed seems to have been reached, convincing top executives—who a few years ago left benefits administration to mostly low-level managers—that their fringe benefits programs need a trimming. "The fringe binge," declares an employee benefits consultant, "is over."

The past year has seen a mobilization of employers in the form of local and regional business coalitions and national organizations like the Business Roundtable. Prominent chemical industry spokesmen like former Du Pont chairman Irving S. Shapiro, Goodrich chairman John D. Ong, and others have begun speaking widely on the subject.

"Can we afford $1 trillion for health care?" former Secretary of Health, Education & Welfare Joseph A. Califano Jr. asked in a speech to the Economic Club of Detroit in April. Califano went on to predict that the nation's health care bill of $321 billion in 1982 ($77 billion of that in corporate health insurance premiums) would climb that high over the next 10 years if changes were not made. "With inflation increasingly coming under control as consumer and wholesale price indices level off," he said, "health care stands out as the single most inflationary factor in the U.S. economy today."

Indeed, the consumer price index (CPI) for all medical care items, which stood at a manageable 106% of the CPI for all items in 1972, had shot up to 114% of the major measure of inflation by 1982. According to a forecast made by the New York City benefits consulting firm Towers, Perrin, Forster & Crosby (TPFC), the medical care index could be as much as 129% of the general CPI by 1984. Even more telling is the index for hospital room costs. Already running at 139% of the general CPI in 1972, the hospital room index was up to 193% in 1982, and, the firm predicts, could rise to as much as 225% of the general CPI in 1984.

Critics of the current health care system insist that this condition can be cured. Medical costs inflate faster than the overall economy, they contend, because health care service operates outside the competitive market system. Hospitals charge on a cost-plus basis, and doctors on a fee-for-service basis. "Thus," says Califano, now a director at Chrysler Corp., "the more hospitals spend, the more they receive. The more services doctors perform, the more money they make."

The situation is particularly vexing to business people used to thinking in terms of supply and demand. Even as medical cost inflation is accelerating, hospital bed occupancy rates around the country range from only 60 to 80% That spells overcapacity, but instead of re-

Air Products employees are encouraged to jog to better health as part of the company's wellness program

sponding as a normal business should by cutting prices, critics say, hospitals simply schedule more services to bring in the necessary income. There is thus a structural incentive, critics say, for the performance of, at worst, unnecessary work and, at best, work that could be done far more inexpensively outside the hospital.

"There are too many hospital beds and too many doctors," remarks David L. Glueck, a vice president at TPFC. "That's the perversity of the health care system: Excess supply means higher prices."

Statistics seem to bear out much of this criticism. In 1950, for instance, the rate of hospital admissions in the U.S. was just 111.4 per 1000 people. But the rate of admissions has been rising steadily since then and accelerated during the 1970s (spurred to a certain extent, no doubt, by the surge in malpractice suits in those years). In 1980, 165.8 people per 1000 population checked into a hospital during the year.

The central argument of corporate employee benefits administrators is that cost efficiency could be attained in the health care system by bringing doctors and hospitals more into the competitive economy. That, plan administrators say, depends on shaping employees into, as the Goodrich brochure puts it, "cost-conscious health care consumers." And that, the argument continues, will happen only when employees have to take more money out of their own pockets to pay for their medical care.

The implication that a good deal of the nation's current health care mess can be laid to a kind of employee profligacy is a corporate view that has proved predictably nettling to many, especially those who contend that one doesn't have the choices of a consumer when it comes to medical care.

"We don't believe in this company philosophy that workers are to blame for the high costs of medical care, that the reason costs are so high is because workers are using [medical care services] too much," declares Jerry Archuleta, a spokesman for the Oil, Chemical & Atomic Workers International Union. "Workers don't have any choice. Nobody goes to the doctor until he is quite ill, and then the decision is out of his hands."

But defenders of more cost-sharing have evidence to support at least part of their argument, notably from the preliminary results of a study by Rand Corp. A long-term survey of 7706 people representing a variety of insurance plans with different levels of deductibles and coinsurance (the ratio at which the insurer and the insured share expenses after the exhaustion of the deductible) found that people who are covered in full for medical services spend as much as 60% more than do people who pay coinsurance.

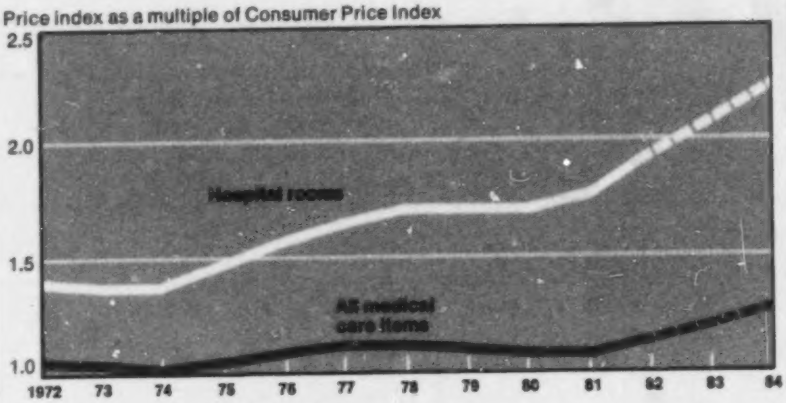
The idea that modifying employee behavior in health care consumption can have more than short-term consequences is both the crux of corporate thinking on the subject and the best means employers have to persuade employees that cost sharing is for their own good. Forcing employees to pay more of their medical expenses is more than just a way to buffer the employer's bottom line, companies say. Ultimately, it is a way to bring down health care costs overall.

The second half of the argument is not provable yet, of course, and companies changing their benefits plans realize they can hardly hope to do so without encountering a good deal of white-collar disgruntlement and blue-collar distrust. In fact, despite the great number of companies transferring out-of-pocket expenses back to employees, many benefits consultants point out, the scale of the costs involved is relatively small, and in many cases companies are adding new benefits as compensation of a kind for those taken away.

Still, chemical companies are finding that employee benefits have become such a big ticket item that they are beginning to have a direct effect on the bottom line. Hercules, for instance, which is activating a new health care plan July 1, says that with the old plan, its 1983 contributions to employee health care probably would be some 23% higher than the 1982 bill, instead of the 15 to 18% to which it now hopes to limit the increase. In 1970, a Hercules spokesman says, the company's health care expenses totaled $5.5 million. In 1982, the company spent $23 million. Without its new cost-sharing plan, Hercules forecasts it would be spending $152 million in 1992. Even so, it expects a bill of about $86 million that year.

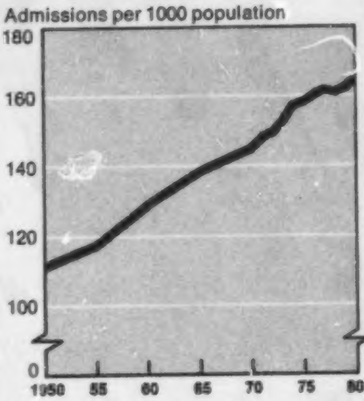
And Du Pont, which gradually began introducing its new health care plan at company facilities around the country 15 months ago, reports that its expenditures for providing basic medical coverage to employees, pensioners, dependents, and survivors rose from $32 million in 1970 to $156 million in 1982. Only the company's tenth most expensive benefit in the mid-1960s, health care now ranks third behind vacations and pensions.

Employees of the chemical industry have long had the reputation of being very well treated when it comes to benefits. The majority of chemical company health in-



Inflation in medical care is greater than general inflation

Sources: Department of Commerce; Towers, Perrin, Forster & Crosby



Hospital admissions have risen steadily

Note: Data refer to civilian, noninstitutional population. Sources: American Hospital Association, Health Insurance Association of America

surance plans have been the traditional combination of basic and major medical coverage, along the lines of Blue Cross and Blue Shield. Employee premiums, when they have been levied (more frequently to hourly than to salaried employees), have been low. So have been deductibles when they existed. First-dollar coverage has been common, and coinsurance relatively rare.

Among the new plans now evolving, certain basic similarities can be discerned. Deductibles are either imposed for the first time or raised to a higher level. Coinsurance is set or maintained at an 80/20 insurer-to-insured ratio for most nonelective medical procedures, and, in some cases, set at a 50/50 ratio for some elective services. At the same time, companies have instituted out-of-pocket limits, also called stop-loss provisions, in cases when coinsurance applies. With a stop-loss provision, an employee's out-of-pocket expenses in a given year are limited to a set total of his or her deductible plus copayments.

The other element common to most revamped plans is a package of financial incentives to use alternatives to inpatient medical care when possible. Under most new programs, an employee has more coverage for many forms of testing, minor surgery, and emergency treatment when they are performed on an outpatient basis. Companies are particularly urging second and even third opinions on the need for nonemergency surgery and the use of preadmission testing on an outpatient basis just before a hospital stay.

The two basic goals of all the new plans are to pass some of the losses back to the employee and to steer the employee into using cheaper coverage when possible. Where these fundamental similarities end, however, a great deal of diversity begins.

The new Hercules health care plan, for example, dispenses with the traditional insurance categories and divides its coverage into three groups based on cost-sharing ratios. The old first-dollar coverage is reserved mostly for the kinds of services whose use the company encourages as an alternative to more expensive hospital care or as preventive measures likely to improve health. These include preadmission testing, outpatient surgery and emergency care, home health care in place of hospitalization, "well" baby care, immunizations, annual Pap smear, and hospice charges.

Most of the rest of the Hercules coverage is on an 80/20 coinsurance basis. After an annual $200 individual or $400 family cash deductible, the company pays 80% of expenses for such services as hospital room and board, inpatient physician, anesthesia, drugs, birthing centers, convalescent facilities, chiropractic, addiction rehabilitation, and home health care. There is a stop-loss provision at $1000 (in addition to the deductible).

As new plans go, the Hercules program is simple in format. More complex, because it offers a number of cost-sharing options, is Goodrich's new health care benefits plan. Under the variations, an employee's annual premium rises or falls in inverse proportion to the amount of risk he or she assumes. A single employee willing to accept the plan's highest deductible and copayment limit—$400 and $1000, respectively—pays no premium. At the other end of the scale, a single employee can cut the deductible to just $100 and the annual copayment limit to $400 by paying a premium.

In addition, the Goodrich plan offers employees another option, one that is gaining increasing acceptance among companies—health maintenance organizations (HMOs). In place of normal insurance coverage, an employee can enroll in an HMO, which provides all necessary health care services on a first-dollar basis for a fixed premium. To employers, the attraction of the HMO is the fixed premium; to employees, the lack of deductible and, theoretically, unlimited access to service. But there still are relatively few HMOs in the U.S., so only some employees can take this option.

Plans like Goodrich's put employees "in charge" of their health care expenses by offering them the incentive to keep them down. If employees are healthy and believe

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Most chemical companies are revamping health care benefits

Statistical evidence on trends in health care cost containment is scanty, but what exists suggests that the chemical industry is moving to revise employee health care benefits at least as fast as, if not faster than, the rest of the U.S. business community.

A C&EN survey this month of the 30 largest firms (in terms of chemical sales) shows a high level of concern about health care costs in the industry. For example, when asked (Question #1) by what per cent each company's contribution to employee health care was expected to rise from 1982 to 1983, the median response was about 16%. C&EN also asked each company (Question #2) whether it had developed a new health care cost management strategy in the past two years, or was planning to do so soon. Of the 28 firms that answered, 16 had recently changed plans and seven were planning to do so in the near future. Other survey questions touched on the specifics of the new employee health care plans: (Question #3) Had the company raised employee deductibles and/or raised the employee share in coinsurance?; (Question #4) Were there options in the plan (could employees choose a lower deductible by paying a higher premium, for example)?; and (Question #5) Did the new plan apply to all employees?

The responses seem to place the chemical industry in the vanguard of the nationwide business attack on health care cost inflation. When William M. Mercer Inc., a unit of Marsh & McLennan, asked 1420 U.S. firms similar questions last year, it learned that only 30.6% of those that replied had implemented new health care cost management strategies. Among the biggest companies (over 50,000 employees), however, 56.3% had new plans, more in line with the C&EN survey results.

It also seems clear that the chemical industry's activities to control health care costs have mushroomed very recently. Only last summer, when the management consulting firm Towers, Perrin, Forster & Crosby conducted a survey on health cost containment, the chemical industry appeared much less enthusiastic. When asked about increases in deductibles and other changes, 12% or fewer of the chemical companies replied that they had made any. Only 16 to 44% said they might do so. The rest doubted they ever would.

The C&EN survey suggests, among other things, that those doubters may be becoming believers. Following are the responses to the C&EN survey:

Company	Question 1	Question 2	Question 3	Question 4	Question 5
Air Products	15%	No	DA	DA	DA
Allied	18	Yes	Deductible	No	Salaried only
American Cyanamid	NA	Consider	DA	DA	DA
American Hoechst	10–15	No	No	DA	DA
Ashland Oil	10	No	DA	DA	DA
Atlantic Richfield	15–25	Yes	DA	DA	DA
Borden	7–13	Yes	Both	No	All salaried, some union
Ciba-Geigy	NA	Yes	NA	NA	NA
Dow Chemical	17	Yes	Both	No	All
Du Pont	NA	Yes	Both	Yes	All
Eastman Kodak	NA	Yes	NA	Yes	All
Ethyl	15–20	Yes	Deductible	No	Salaried only
Exxon Chemical	9.4	Yes	Both	Yes	NA
W. R. Grace	15–18	Yes	Both	No	Salaried only
Gulf Oil	9.7	Yes	Both	No	Most salaried, some union
Hercules	15–18	Yes	Both	No	All nonunion, some union
Mobay	15–18	Plans to	DA	DA	DA
Mobil	17	Consider	Deductible	No	All
Monsanto	12	Yes	Not yet	DA	DA
Occidental Petroleum	15	1984	Both in 1984	No	Salaried only
Phillips Petroleum	20	Consider	Both	No	All
Rohm & Haas	8–15	Yes	Both	Yes	All, except some union
Shell Oil	NA	Yes	Both	No	All
Standard Oil (Ind.)	20	Yes	Deductible	No	All salaried, most hourly
Stauffer Chemical	15–18	Yes	Both	No	All salaried, some union
Texaco	NA	Consider	Deductible	Yes	All
Union Carbide	15	Yes	No	DA	DA

NA = No answer. **DA** = Doesn't apply. **Note:** In Question 5, "some union" generally means that companies are implementing new plans with unions as contracts come up for renegotiation. Union Oil declined to answer the survey questions because labor negotiations are in progress. Celanese and FMC declined to answer any questions.

they can limit their utilization of medical services, they can choose a plan option with a low or zero premium. In addition, Goodrich sweetens the pot with a reimbursement account, an innovation that is becoming increasingly common. Reimbursement accounts give each employee a health care "bank." At Goodrich, it totals $300. The company withdraws the employee's premium from the account, and the employee can apply what remains to deductibles, copayments, and certain services not covered by the health plan (typically dental and vision care). In most cases, if there is money left in the reimbursement account at the end of the year, the employee receives it as a cash payout.

"The company is betting that a reimbursement account will make an employee smarter about health care utilization," comments Dean Sontag, a consultant specializing in health care cost containment at Hewitt Associates, a Chicago benefits consulting firm.

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Du Pont, with an eye to employee relations, offers an even more flexible option. Employees can choose traditional basic and major medical coverage on a contributory basis. Coverage is mostly from the first dollar on. Cost sharing is fundamentally limited to a $200 deductible on major medical and to 20% of hospitalization charges after 365 days. Under Du Pont's "Different Option" plan, there is less first-dollar coverage, a $200 deductible is in effect for some services, and only 90% of hospital room charges are paid. On the other hand, there is no premium, hospital room coverage remains at 90% for an unlimited time, and there is an out-of-pocket limit of $1000 per patient.

Both Du Pont plans include provisions that encourage the use of extended-care facilities, home health care agencies, hospice services, birth clinics, outpatient testing, and second surgical opinions. In addition, the "Different Option" gives more coverage—up to $1 million per year—than the traditional plan, which has a liftime maximum of $250,000.

The Hercules, Goodrich, and Du Pont plans provide a good sample of the range of revised health care benefits that are emerging in the chemical industry today. Typically, the amounts of money involved in deductibles and copayments are relatively small. In plans with reimbursement accounts, much of an employee's cost sharing may end up being returned anyway. Clearly, chemical companies are interested in changing the way their employees utilize health care services. What is not yet clear, however, is which alternative medical services will actually cost less and reduce health care costs in the long run.

Most problematic to companies considering alternative coverage are HMOs. Proponents of HMOs say that because such operations must provide all necessary health care for a fixed price, they have a strong incentive to operate efficiently by performing only those services that really must be done. If there are enough HMOs, they eventually become a cheaper alternative to hospitals for many services.

"We favor the approach of introducing competition into the health care system," says Kathy Lewis, director of the consulting division of InterStudy, a nonprofit research and policy group in Minneapolis. "And we think HMOs are the way of doing that."

But HMOs have their detractors, too. There were only 269 HMOs nationwide at the beginning of this year with enrollment of just 11.6 million people, according to a census conducted by InterStudy. Except in a few locations like Minneapolis, they are so scattered that they cannot accommodate enough of the patient market to apply much competitive pressure to hospitals.

"HMOs appear to be a valid strategy where there are many of them," says Hewitt's Sontag. In the Minneapolis/St. Paul area, he notes, HMOs serve about 27% of the employed patient population. "Health care costs there are less than overall medical inflation in the U.S., so where there is a broad base, there is success."

"HMOs are playing an increasing role in health care," remarks TPFC's Glueck, "but the jury is still out on how effective they are at keeping costs down."

Most HMOs are of such recent vintage that many analysts believe it is still too early to determine whether they will be able to keep their premiums the same as or lower than those of traditional indemnity plans. In a 1982 survey of 240 employers that offer HMOs, Hay Management Consultants, a Philadelphia health benefits consulting firm, found some 35% of the companies said the administrative cost of their HMO was less than that of their indemnity plan. About 39% said they were about the same. Only 14% say HMOs cost more. But InterStudy reports that the average HMO premium of $150.98 for a family in mid-1982 was up 14.3% from 1981, compared to a rise in the medical cost component of the CPI of 12% during that period.

HMOs need membership to keep costs down and to

Key terms in the health care debate

Coinsurance. A policy provision frequently found in major medical insurance by which both the insured person and the insurer share the covered losses under a policy in a specified ratio, for example, 80% by the insurer and 20% by the insured. Coinsurance payments (copayments) usually begin after a deductible is exhausted.

Comprehensive medical insurance. A policy designed to give the protection offered by both a basic and a major medical health insurance policy. It is characterized by a low deductible amount, a coinsurance feature, and high maximum benefits.

Deductible. The amount of covered charges incurred by the protected person which must be assumed or paid by the insured before benefits by the insurance company become payable.

Health maintenance organization (HMO). An organization that provides a wide range of comprehensive health care services for a specified group at a fixed periodic payment.

Preferred provider organization (PPO). An organization formed by employers, insurance companies, hospitals, doctors, or doctor groups in which a specified portion of the medical community contracts to provide services on a controlled basis. Services frequently are discounted, and utilization review is common.

Reimbursement account. An account typically totaling several hundred dollars established by an employer for employees under a comprehensive insurance plan. Employees can draw the account toward deductibles, copayments, or eligible medical services not covered by the health care plan.

Stop-loss provision. A limit to an employee's annual out-of-pocket expenses, generally a combination of deductible and copayments, after which the insurer begins paying 100% of expenses.

Wellness programs. Company-sponsored health promotion programs, typically consisting of various forms of health-related counseling and instruction and physical fitness activities.

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Glueck (far left) of Towers, Perrin, Forster & Crosby says "the jury is still out" on the question of how effective health maintenance organizations (HMOs) are at keeping health care costs down. Carter of Hay/ Huggins, however, is pessimistic about the future viability of HMOs in the U.S.

prosper over time, but some analysts believe their growth potential is limited because most of their services generally are offered in a clinic.

"HMOs have a low participation rate, so they can't make much of a dent in overall health care costs, and that's because they're not yet accepted by the American public," says Michael F. Carter, a vice president of Hay/Huggins, the benefits consulting division of Hay Management Consultants. "I don't think HMOs will bring down costs in the long run. Americans don't have the HMO mentality. They don't trust the clinic concept."

But even as a number of analysts are beginning to think the impact of HMOs on the health care system ultimately will be limited, a new alternative is emerging: the preferred provider organization (PPO). These are organizations formed between employers, insurance companies, hospitals, or doctors' groups in which a specific portion of the medical community contracts to provide services on a controlled basis. In many cases, discounts are offered because large employers can use their employee population as market leverage. Even more important, analysts point out, the medical community guarantees it will meet agreed-on standards for efficiency and utilization of services.

The major differences between PPOs and HMOs are, first, that PPOs operate on a fee-per-service basis, and, second, that they do not operate as clinics. Patients go to see whichever doctor they prefer in a normal office setting, as long as the doctor is part of the PPO. Companies steer employees toward preferred providers through incentives. A medical plan might pay 100% of fees for services through a PPO, say, but only 80% of fees for the same services elsewhere.

The idea of PPOs appeals to many companies, in theory at least, because they are a more direct way of putting health care on a competitive basis. Insurers can "cut deals." But the problem with PPOs is that there are so few of them. "Only large employers have the clout to do it," remarks Hay/Huggins' Carter. "That's why there are only a handful of them."

In the end, employers realize that there probably is a limit to how much they can control losses by prodding employees to use less-expensive services. Most companies with new health care plans say their goal is merely to hold cost increases down to the level of overall inflation. But type of service is only one of the variables open to manipulation. The other is the very health of the employees. The argument is simple: If employees get sick less, they will use medical services less.

"Although it seems simplistic, the reason for rising health care costs, at the most basic level, is that our employees and their dependents get sick," says Denise Maleska, head of the task force that designed Ciba-Geigy's new health care benefits plan. "Based on our task force studies, we concluded that if we could work toward improved employee and family health, we would be able to slow health care cost escalation. Cost containment measures alone have an immediate effect, but they won't change long-standing lifestyle factors that cause most serious illnesses."

The strategy at Ciba-Geigy and elsewhere is the "wellness" program, a catchall term for a variety of measures taken to promote employee health. Wellness programs typically consist of various forms of health-related counseling and instruction, and, in fewer cases, physical fitness programs. Ciba-Geigy, for instance, offers employees newsletters on health and lectures directed at smoking, hypertension, stress management, weight control, and others. In addition, the company is sponsoring 10-week courses in physical fitness and aerobic dancing.

Air Products also runs a varied wellness program that stresses weight control and quitting smoking, according to Lloyd Tepper, corporate medical director. Other programs include stress management and back strengthening. There is also a loosely defined physical fitness program consisting of some aerobic dance classes and encouragement for joggers.

Tepper believes that the value of a wellness program goes beyond the number of employees who actually participate in it. "We feel strongly about programs like running," he says, "because it does a lot even for those who don't run. There is peer pressure and cross-fertilization of attitudes toward fitness. It becomes part of the company culture to have a spring in your step."

The problem with wellness programs is that it is nearly impossible to quantify their effectiveness. "You can't measure the results," Tepper says, "so you piggyback on the evidence of other studies. For the benefits of smoking cessation, for example, there is solid evidence. And counseling on substance abuse [alcoholism and drug abuse] clearly pays for itself. You can measure that in terms of absenteeism and the consumption of health care benefits."

"We recommend [wellness programs]," says Hay/Huggins' Carter, "but they're not to be done in a half-hearted way. That would be a waste of time and money. They need to be coordinated and convenient."

Even supporters of wellness programs like Carter, however, caution that a company's expectations must be moderate. At one of Hay/Huggins' client companies, for example, about 25% of the employees joined an exercise program. About half of them responded to a survey that they would have been exercising anyway without the company program, so the consulting firm figures that, at best, some 10 to 15% of the company's employees' behavior was changed for the better.

It is difficult to convince many analysts that the expense involved in organizing counseling and setting up a gymnasium is justifiable. "It's up in the air," remarks Hewitt's Sontag. "A full-blown program could cost more than the actual savings." And TPFC's Glueck attacks even stop-smoking programs. "The recidivism rate is in excess of 90%," he declares. "It's nothing but window dressing."

Sontag and Glueck concede, however, that there is probably a certain useful propaganda value to wellness programs. "Engendering a wellness philosophy in an organization will eventually pay off," Sontag says.

At the same time that they are revamping in-house programs, chemical companies and others are also vigorously taking their message to hospitals, doctors, and the government. The past few years have seen an explosion of employer health coalitions on the local, regional, and national levels, all of them jawboning the medical community and lobbying legislatures. At the top of the heap is the Washington Business Group on Health, a lobbying group representing 200 major companies. The Business Roundtable has a task force on health with state chapters. And chemical companies belong to an increasing number of associations based in major cities.

Monsanto, for instance, participates in a business health coalition in St. Louis. Like many other such groups, the St. Louis coalition has concentrated on convincing doctors to accept practices that will reduce costs. "Most of the initial efforts of the coalition have been to work out an agreement with the medical and hospital associations and the local professional service review organization to make private-sector hospital utilization review available in the community," says Robert N. Abercrombie, Monsanto's manager of benefits operations.

Atlantic Richfield Corp. belongs to the Employers Health Care Coalition of Los Angeles, one of 10 such coalitions in California. The Los Angeles group has a long list of objectives related directly to the medical community. Primarily, it would like to get hospitals to agree to utilization review by local physicians and to consider preadmission certification, retrospective reviews of hospital use through the analysis of employee health data, and the use of claims data to identify providers who appear to be providing services inefficiently, among other objectives. In addition, the coalition would negotiate discounts with hospitals where increased volume warrants it.

Legislatively, coalitions have immediate worries. The tax-capping bills before Congress would limit the amount of money spent on employee health benefits that companies could write off their taxes. And in California last year, employer health care coalitions had their hands full helping fight attempts by the California Medical Association to kill a fledgling law allowing the private sector to contract for health care with PPOs.

The California Medical Association's antagonism to that legislation is an example of the ambiguous relationship of the medical community to this mushrooming national business health care movement. The American Medical Association (AMA) officially supports health care coalitions whose objective is to restrain health care cost inflation. According to a spokesman, AMA even accepts the general premise that health care services would be better for competition.

"Admitting competition is just a recognition of reality," a spokesman says. "AMA is trying to assist physicians to be competitive by being more efficient."

But the doctors' group remains profoundly uneasy with anything that even suggests socialized medicine. That is why the California chapter opposed the PPO bill and why AMA as a whole is ambivalent toward some of the innovations businesses are now proposing.

For employees of chemical companies, this year's and the recent past's round of health care benefit cutbacks is probably just a faint sign of things to come. Analysts point out that in most cases, cost-sharing provisions are quite small. Instead of deductibles averaging $100 to $200, they say, companies should have gone to $500. And they will, the analysts predict, as soon as they find a way to do it without rupturing employee relations.

And retrenchment in medical care may signal an eventual turn toward retrenchment on other employee benefits. Health care benefits costs, after all, are the most egregious case. The most expensive benefits are pensions, another long-time sacred cow that, analysts warn, could very well be the next benefit to be reconsidered by employers.

"Companies now are focusing on health care costs because they are out of control," says Hay/Huggins' Carter. "The reality is that the others are out of control, too. They will stand some hard looking at." □

Profitability Plummets at U.S. Chemical Companies

Profit margins and return on investment, assets, and equity all declined last year from 1981; specialty firms continue to top profitability rankings

William J. Storck, C&EN New York

Along with practically every other financial measure, profitability among U.S. chemical companies suffered in 1982 as the recession dug deeper and deeper into operations. Rates of return for the industry and indeed for most companies dropped sharply last year compared with 1981.

In a survey of 36 U.S. chemical companies, C&EN found that profit margins (net earnings as a percentage of sales) dropped to 4.1% last year from 5.6% the year before. Return on investment (net income as a percentage of current assets plus gross plant) fell to 3.1% in 1982 from 4.8% in 1981. Return on assets (net income as a percentage of total assets) dropped to 4.1% from 6.2%. And return on equity (net income as a percentage of year-end stockholders' equity) fell to an average of 8.5% from 13.4% in 1981.

As in previous years, companies with more narrowly focused and higher value-added product lines dominated the top profitability rankings.

However, unlike previous years, fertilizer-dominated companies did not rank particularly high in any of the rankings, except for profit margins, as the fertilizer business cycle seems to have run its course. This decline appears to have started in 1981, when only one fertilizer producer, Freeport-McMoRan, was able to take a first place, in profit margin. In 1982, however, the best that the fertilizer companies could do was a second place—again, it was Freeport—in profit margin. However, Freeport's other profitability rankings were low enough to drop it to

The top companies in overall profitability

1 International Flavors
2 Nalco Chemical
3 Petrolite
4 Chemed
5 Great Lakes Chemical
6 First Mississippi
7 Loctite
8 International Minerals
9 W. R. Grace
10 Freeport-McMoRan
10 Lubrizol

Profit margins at U.S. chemical companies fell to 4.1% in 1982

Rank[a]			Profit margin[b]	
1982	1981		1982	1981
1	2	International Flavors	14.1%	14.7%
2	1	Freeport-McMoRan	12.0	19.1
3	9	First Mississippi	10.4	8.3
4	3	Nalco Chemical	10.0	12.2
5	7	Petrolite	9.7	9.4
6	4	Great Lakes Chemical	9.4	11.7
7	11	International Minerals	7.8	7.7
8	8	Stauffer Chemical	7.7	8.7
9	25	Loctite	7.3	4.9
10	10	Air Products	6.8	8.0
11	6	Chemed	6.7	10.0
12	12	Liquid Air	6.1	7.4
13	5	Lubrizol	5.9	10.2
14	20	Ethyl	5.8	5.2
15	17	W. R. Grace	5.2	5.5
15	14	Monsanto	5.2	6.4
17	16	PPG Industries	4.7	6.3
17	25	Rohm & Haas	4.7	4.9
19	35	Stepan Chemical	4.4	3.2
20	20	FMC	4.3	5.2
20	13	National Distillers	4.3	6.7
22	28	Essex Chemical	4.0	4.7
23	18	American Cyanamid	3.8	5.4
24	23	Hercules	3.5	5.0
24	29	Olin	3.5	4.6
26	14	Union Carbide	3.4	6.4
27	27	Dow Chemical	3.2	4.8
28	30	H. B. Fuller	2.6	4.1
28	32	Pennwalt	2.6	3.5
30	36	Witco Chemical	2.3	3.0
31	40	GAF	2.0	def
32	32	Crompton & Knowles	1.8	3.5
32	23	Williams Cos.	1.8	5.0
34	38	Reichhold Chemicals	0.6	1.6
35	31	Celanese	0.2	3.8
36	37	B. F. Goodrich	def	2.9
		AVERAGE[c]	4.1%	5.6%

a Ranking for 1981 is as it appeared in previous survey (C&EN, June 7, 1982, page 17). b After-tax income as a percentage of sales. c Average is for companies listed in previous survey. def = deficit.

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Return on investment dropped to 3.1%

Rank[a]			Return on investment[b]	
1982	1981		1982	1981
1	1	**Chemed**	14.0%	15.1%
2	3	**International Flavors**	12.4	13.1
3	2	**Nalco Chemical**	11.1	14.5
4	5	**Petrolite**	10.8	11.0
5	22	**Monsanto**	8.3	5.1
6	16	**Loctite**	7.7	5.7
7	7	**Great Lakes Chemical**	6.7	8.5
8	4	**Lubrizol**	6.0	11.5
9	9	**First Mississippi**	5.8	7.8
10	18	**Ethyl**	5.5	5.5
11	11	**W. R. Grace**	5.4	7.2
12	14	**International Minerals**	4.9	6.1
13	35	**Stepan Chemical**	4.8	3.4
14	10	**National Distillers**	4.5	7.7
15	19	**FMC**	4.4	5.3
15	15	**Stauffer Chemical**	4.4	5.8
17	26	**Rohm & Haas**	4.3	4.7
18	6	**Freeport-McMoRan**	4.2	8.8
19	13	**Essex Chemical**	4.0	6.6
19	21	**Liquid Air**	4.0	5.2
21	8	**H. B. Fuller**	3.8	7.9
22	26	**Air Products**	3.6	4.7
23	19	**PPG Industries**	3.5	5.3
23	29	**Witco Chemical**	3.5	4.3
25	24	**American Cyanamid**	3.2	4.8
26	24	**Hercules**	3.0	4.8
27	16	**Crompton & Knowles**	2.9	5.7
28	30	**Olin**	2.5	3.9
29	31	**Pennwalt**	2.4	3.7
30	33	**Dow Chemical**	2.3	3.6
30	40	**GAF**	2.3	def
32	26	**Union Carbide**	2.2	4.7
33	36	**Reichhold Chemicals**	1.0	3.3
33	34	**Williams Cos.**	1.0	3.5
35	37	**Celanese**	0.1	3.1
36	38	**B. F. Goodrich**	def	2.7
		AVERAGE[c]	**3.1%**	**4.8%**

a Ranking for 1981 is as it appeared in previous survey (C&EN, June 7, 1982, page 17). b After-tax earnings as a percentage of current assets plus gross plant. c Average for 1981 is for companies listed in survey. def = deficit.

10th place in terms of overall profitability. One other mineral-dominated company, First Mississippi, was much more consistent. Its place on all four profitability rankings was high enough to give it sixth place in terms of overall profitability.

The profitability leaders are figured by adding their rankings. The lowest ranking is then considered to represent the best overall profitability.

International Flavors, by this method, came in first. It scored first place in both profit margin and return on assets, second in return on investment, and fourth in return on stockholders' equity.

The second-best company in terms of overall profitability—Petrolite—led in no category. However, it was fairly consistent in all of them with rankings of fifth in profit margin, fourth in return on investment, and second in return on assets and return on equity. Nalco Chemical, tied with Petrolite for second, placed fourth in profit margin and third in return on investment, return on assets, and return on equity.

Return on assets declined to 4.1% last year

Rank[a]			Return on assets[b]	
1982	1981		1982	1981
1	2	**International Flavors**	14.6%	15.3%
1	3	**Petrolite**	14.6	14.1
3	1	**Nalco Chemical**	13.9	17.4
4	5	**Chemed**	10.1	10.9
5	7	**Great Lakes Chemical**	8.1	10.6
6	28	**Loctite**	7.9	5.7
7	4	**Lubrizol**	7.4	13.7
8	16	**W. R. Grace**	6.5	7.2
9	12	**International Minerals**	6.3	7.8
9	19	**Rohm & Haas**	6.3	6.9
11	16	**Ethyl**	6.2	7.2
12	8	**First Mississippi**	5.9	9.3
13	14	**Stauffer Chemical**	5.7	7.4
14	37	**Stepan Chemical**	5.6	3.7
15	24	**FMC**	5.5	6.4
16	6	**Freeport-McMoRan**	5.4	10.8
16	15	**Monsanto**	5.4	7.3
18	22	**Liquid Air**	5.1	6.5
19	21	**Air Products**	4.9	6.7
20	13	**Essex Chemical**	4.7	7.6
20	18	**PPG Industries**	4.7	7.1
22	10	**National Distillers**	4.6	8.0
23	30	**Witco Chemical**	4.5	5.3
24	24	**American Cyanamid**	4.4	6.4
25	20	**Hercules**	4.3	6.8
26	9	**H. B. Fuller**	4.2	8.6
27	28	**Olin**	3.9	5.7
28	32	**Pennwalt**	3.2	4.7
29	27	**Crompton & Knowles**	3.0	6.0
30	33	**Dow Chemical**	2.9	4.5
30	26	**Union Carbide**	2.9	6.2
32	40	**GAF**	2.8	def
33	26	**Williams Cos.**	1.3	4.0
34	35	**Reichhold Chemicals**	1.3	4.2
35	37	**Celanese**	0.2	4.8
36	38	**B. F. Goodrich**	def	3.4
		AVERAGE[c]	**4.1%**	**6.2%**

a Ranking for 1981 is as it appeared in previous survey (C&EN, June 7, 1982, page 17). b After-tax income as a percentage of total assets. c Average is for companies listed in previous survey. def = deficit.

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Return on stockholders' equity plummeted to 8.5%

Rank[a]			Return on equity[b]	
1982	1981		1982	1981
1	16	**Chemed**	33.6%	13.8%
2	5	**Petrolite**	20.6	21.4
3	1	**Nalco Chemical**	19.1	24.2
4	6	**International Flavors**	18.8	20.0
5	28	**Stepan Chemical**	16.7	12.1
6	2	**Essex Chemical**	16.0	23.8
6	4	**First Mississippi**	16.0	21.5
8	10	**W. R. Grace**	14.6	17.5
9	11	**Great Lakes Chemical**	13.6	16.5
10	36	**Loctite**	12.8	8.6
11	3	**Freeport-McMoRan**	12.3	22.5
12	13	**International Minerals**	12.1	15.8
13	24	**Ethyl**	11.7	12.6
14	12	**Air Products**	11.5	16.3
15	15	**Stauffer Chemical**	11.4	14.6
16	17	**FMC**	11.3	13.6
17	25	**Rohm & Haas**	10.6	12.3
18	9	**H. B. Fuller**	10.5	17.9
19	7	**Lubrizol**	10.3	19.7
20	20	**Witco Chemical**	10.0	13.0
21	27	**Liquid Air**	9.8	12.2
22	19	**Monsanto**	9.4	13.4
23	20	**PPG Industries**	9.1	13.0
24	23	**American Cyanamid**	8.6	12.9
25	20	**Hercules**	8.1	13.0
26	17	**National Distillers**	7.8	13.6
26	29	**Olin**	7.8	11.7
28	31	**Dow Chemical**	6.8	11.5
29	40	**GAF**	6.7	def
29	35	**Pennwalt**	6.7	9.5
31	25	**Union Carbide**	6.0	12.3
32	31	**Crompton & Knowles**	5.5	11.5
33	34	**Williams Cos.**	2.9	9.6
34	33	**Reichhold Chemicals**	2.8	9.8
35	29	**Celanese**	0.4	11.7
36	37	**B. F. Goodrich**	def	8.4
		AVERAGE[c]	**8.5%**	**13.4%**

a Ranking for 1981 is as it appeared in previous survey (C&EN, June 7, 1982, page 17). b After-tax income as a percentage of year-end stockholders' equity. c 1981 average is for companies listed in previous survey. def = deficit.

Chemed led in the other two rankings, return on equity and return on investment, and it had fourth place in return on assets. However, its eleventh place in profit margin pulled it down so that it could do no better than fourth place in overall profitability.

Although in general, the smaller, more specialized companies were the leaders in almost all categories, one large chemical company, W. R. Grace, managed a respectable performance in terms of overall profitability. Grace ranked 15th in profit margin, 11th in return on investment, and eighth in both return on assets and equity. This was enough to give it ninth place in terms of overall performance.

A few other companies with sales of more than $1 billion did well in one category. For instance, Monsanto was able to garner fifth place in return on investment, up from 22nd place in 1981. Stauffer Chemical, which consistently ranks high in profit margin, came in eighth in 1982, the same position as the year before, despite a decrease in its profit margin to 7.7% last year from 8.7% the year before.

Rohm & Haas was in the top 10 in return on assets, ranking ninth in that category, and Air Products came in 10th in the profit-margin ranking.

One other company with sales of more than $1 billion—Ethyl—managed a 10th place in return on investment.

In general, the falling averages of the company samples were indicative of the way that the individual companies were going. Of the 36 companies surveyed, only seven had a better profit margin in 1982 than they did in 1981, but 29 fell. For return on investment, just four improved in 1982, 31 fell, and one stayed the same. The same number, four, had increases in return on assets, but 32 dropped. Four had improvements in return on equity, but 32 had decreases in their ratios. ☐

About C&EN's profitability rankings

C&EN's rankings of companies for profitability are based on 36 large chemical firms using nonrestated data.

Thus, the 1982 ratios are compared with ratios from data published for the end of 1981 and not restated in 1982 annual reports for 1981.

In addition, the averages that appear at the end of each listing are for the companies that appeared on the list for the respective years. In other words, the 1982 average is for the companies on the list this year. The average for 1981 is for the companies that appeared on a similar list last year (C&EN, June 7, 1982, page 17).

Also, the 1981 rankings are based on the list that was published last year. All of the companies that appear in the rankings this year were included in last year's list, which was made up of 40 companies. The four companies that were dropped this year are Allied, Thiokol, Philip A. Hunt, and Akzona. Allied, after a series of acquisitions, does not have enough chemical sales as a percentage of total sales to make it comparable to the other companies on the list. Akzona was acquired by Akzo and no longer publishes financial data. Most of Philip A. Hunt's sales and earnings are reported through Olin, which would give the effect of double counting if the smaller company were also included. Thiokol has merged with Morton Norwich to make Morton-Thiokol. Although this company undoubtedly will be included in the future, no full-year numbers for the new company are available.

These four companies are still considered in the 1981 rankings, however. Thus, although 36 companies are ranked for 1982, some 1981 rankings go up to 40th place.

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After 50 Years, Polyethylene Producers Face Grim Prospects

Global supply and demand are forecast to grow about 4% a year during 1980s, so many countries will continue to suffer from overcapacity

Dermot A. O'Sullivan, C&EN London

Polyethylene has come a long way since researchers at Imperial Chemical Industries in England made the first few grams of it 50 years ago. From something of a laboratory curiosity it has developed into a truly commodity product with global consumption running at about 40 billion lb annually. Its uses range from making toys, kitchen utensils, and packaging to sophisticated components of radar equipment and telephone cables. To mark polyethylene's golden jubilee, the Plastics & Rubber Institute of the U.K. organized a conference in London earlier this month.

The seemingly insatiable demand for products made from the plastic prompted companies in increasing numbers to go into production. So much so, that the polymer has become something of a victim of its own success. This is particularly the case in Western Europe where demand more than doubled in the past decade from 5.5 billion lb in 1970 to about 12 billion lb in 1979.

Horton: too many producers

"Today the West European polyethylene industry is at a crossroads," Robert B. Horton, managing director of London-based BP Chemicals International, one of Europe's leading producers, told the 280 conference attendees. "The expectation of continued high growth rates has evaporated. Low growth prospects resulting from poor economic conditions plus diminishing replacement opportunities are recognized by the industry. Western Europe now has too many producers as well as too much capacity.

"The combined effect has created an unprofitable industry where most companies fail to cover their cost of production. Respectable returns on capital employed are a long way from being achieved."

All the countries of Western Europe, except Denmark, Ireland, Luxembourg, and Switzerland, have polyethylene-making facilities. There are 17 producers of high-density polyethylene, 21 of low-density polyethylene. This, coupled with a decline in sales as the result of the economic slowdown, resulted in a fall in average plant capacity utilization rates to below 70% in 1980 and 1981.

"There are signs which give grounds for cautious optimism," Horton observes. "Management is adapting to a situation where cost-cutting and making existing assets work harder is the name of the game."

This action has taken the form of plant closures. These started in 1981, gaining momentum last year. The U.K. has led the field with a 34% capacity reduction. Belgium and the Netherlands, combined, and France cut capacity 13%; West Germany, 10%; Italy, 8%.

Largely as a result of these moves, western European polyethylene plant capacity utilization last year advanced to 72%. In Belgium and the Netherlands, where exports helped boost production levels, it was a respectable 84%; in the U.K., 78%. But in France, it remains a relatively low 69%; in West Germany it is 56%; and in Italy a dismal 46%. "There is still a lot of capacity which needs to be closed if a more acceptable supply/

Polyethylene global supply, demand to grow 4% per year

	Supply			Demand		
Billions of lb	1990	1980	Annual growth	1990	1980	Annual growth
Western Europe	23.10	19.14	1.9%	19.80	14.74	3.0%
North America	20.68	13.64	4.2	16.94	11.66	3.8
South America	3.96	1.76	8.4	5.06	2.86	5.9
Africa	1.32	0.44	11.6	1.76	1.10	4.8
Middle East	2.42	0.22	27.1	1.54	0.66	8.8
Pacific	10.56	6.38	5.2	11.88	6.60	6.1
WORLD TOTAL	62.04	41.58	4.1%	56.98	37.62	4.2%

Source: BP Chemicals International

SABIC building three polyethylene plants with partners

Company name	Location in Saudi Arabia	Partner (50% in all cases)	Product	Annual capacity (millions of lb)
Saudi Yanbu Petrochemical (YANPET)	Yanbu	Mobil Oil	Linear LDPE + HDPE	440 (LLDPE) + 198 (HDPE)
Al-Jubail Petrochemical (KEMYA)	Al-Jubail	Exxon	Linear LDPE	572
Eastern Petrochemical (SHARQ)	Al-Jubail	Japanese consortium	Linear LDPE	286

demand balance is to be achieved," Horton comments.

Looking to the future, "our view is that there will be gross domestic product growth [in Western Europe] averaging 1.5% per year over the next five years. This will provide the main stimulus for increasing demand. I have in mind the construction, automotive, and service industries, [and] packaging, which is such a major part of the polyethylene industry."

Based on this premise, Horton believes demand in Western Europe will grow 3% a year on average for the decade as a whole, and local supply capability will increase less than 2% a year. Some might view this projection as somewhat optimistic, particularly in light of the experience of the past two years. But it is more modest than the projection he makes for other areas of the world. For instance, he sees annual demand in North America growing about 4% a year, outpaced by growth in supply capability, largely a reflection of expected developments in Canada.

On the upper end of Horton's demand projection scale is the Middle East, where growth, he believes, might be close to 9% annually. Admittedly, this area is starting from a much lower base than elsewhere. Nevertheless, even if the forecast materializes, it will fall far short of the 27% a year growth in production capability he foresees for the area.

West European polyethylene producers face two additional challenges in the immediate future. One is the emergence of linear LDPE, which, Horton expects, "is destined to be a major product of the future," that eventually will displace a large part of conventional polymer.

"With the development of linear LDPE, the industry now has a product that can overlap into market segments of both HDPE and LDPE," he says. "Its greater mechanical strength compared with LDPE has the effect of breaking down the traditional differentiation between HDPE and LDPE. A likely outcome could be promotion of polyethylene as a whole. Producers could provide a product tailored more closely to the customer, and not be inhibited by the split in polyethylene type."

The other challenge, of course, will come from new production units in Canada and Saudi Arabia. Understandably, therefore, attendees at the conference paid close attention to the comments of Abdulaziz Alzamil, managing director of Saudi Basic Industries Corp. (SABIC), who shared the platform with Horton.

SABIC has seven joint ventures for a variety of petrochemicals based on low-cost methane and ethane, both as energy and feedstock, that otherwise would be flared. Three of these ventures—together with Exxon, Mobil Oil, and a consortium of Japanese companies led by Mitsubishi—will begin making polyethylene in 1985. "We plan to produce 1.3 billion lb per year of linear LDPE, and 198 million lb of HDPE," Alzamil says. "These figures may increase," he adds, "since recent improvements in the [Union Carbide] Unipol process will enable us to expand production.

"In a world context, we will be producing about 3% of an expected world [LDPE] capacity of about 44 billion lb. Our output will equal 35% of Japan's capacity, 9% of Western Europe's, or 10% of the U.S.'s. Our HDPE production will be less than 1% of the 1986 world capacity of about 22 billion lb—15% of Japan's,

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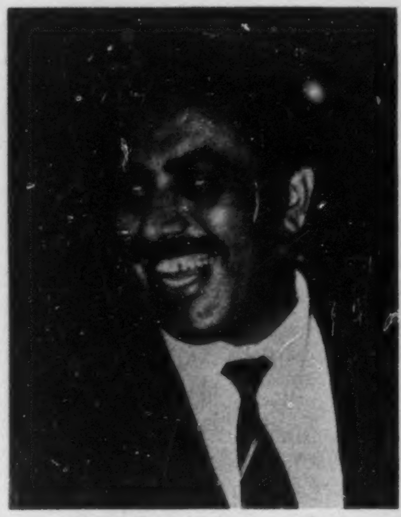

Alzamil: an orderly market

6% of Western Europe's, or 4% of the U.S.'s," he says.

"Even these figures overstate the amount our polyethylenes will add to the [global] market, because we expect domestic and regional demand to take increasing amounts of our production," Alzamil says. "Currently, Saudi Arabia consumes 110 million lb per year of polyethylene, a figure we expect to double by 1990. Moreover, some of our partners will use production from their plants in Saudi Arabia to replace production of their obsolete plants, and will market material through their sales network.

"By 1986, approximately 15% of our production will be consumed by our partners' captive needs. Between these requirements and Saudi Arabia's internal and regional demand, only 40% of our polyethylene is expected to appear on the developed world's markets.

"We strongly believe that our success depends on an orderly market. We do not intend to disrupt world markets. Our goal is to assume our place as a new and responsible producer of an established product.

"Saudi Arabian polyethylene will be of commercial quality comparable with the best in the world. We are prepared to offer it on the same terms as any other seller. But we must be candid in saying that if protectionist measures, or price manipulations, are used to keep us out, we shall counter with our own measures to obtain our rightful place in the market." □

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Firings Up, But Handled Better

The latest report from the American Chemical Society's Committee on Professional Relations (CPR) on mass firings of chemical professionals contains both good news and bad news. The good news is that employers having such multiple terminations are complying more closely than they have in the past to ACS standards that spell out how terminees should be treated. The bad news is a sudden upsurge in the number of mass firings.

This committee, working through its Subcommittee on Professional Standards, over the past eight years has examined 139 multiple terminations of chemists and chemical engineers and compared them with seven standards contained in the society's Professional Employment Guidelines (PEG).

The latest report covers 12 terminations that occurred between the summer of 1981 and the end of 1982. Overall compliance with the standards averaged 56%, up from an average of 42% for the 16 earlier reports of this type and up very sharply from the 31% for the previous report which covered seven layoffs between August 1980 and April 1982.

CPR reports that when the latest report was finalized at the end of March, investigation of an additional 32 multiple terminations was in progress. This was the largest number under active investigation at any one time since the committee started compiling records in 1969.

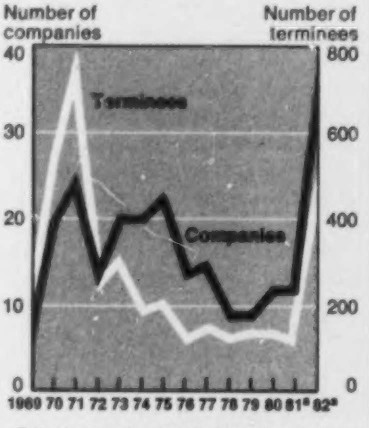
The committee estimates that it will end up investigating close to 40 terminations that occurred in 1982 involving more than 500 terminees. This will represent a very major increase from 12 layoffs involving 134 terminees in 1980, the latest year for which complete data are available.

CPR defines a multiple termination as a situation in which a company or institution terminates the employment of three or more chemists and/or chemical engineers within a six-month period for reasons other than continuing evidence of documented inadequate performance, completion of a contract, or cause.

This and all previous CPR multiple termination reports, which contain detailed information from both employers and terminees, can be obtained on request from American Chemical Society, Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036.

The seven PEG standards on multiple terminations are concerned with advance notice, severance pay, assistance in finding new jobs, pension vesting, employee service, protection plans, and rehire privileges.

Layoffs surge to levels of a decade ago



a Estimates based on investigations already completed and still in progress.

In the latest report, half of the 12 employers investigated met the standard of a minimum of four weeks' advance notice. This was up from 37% compliance for the earlier reports. Five of the 12 met the standard of a minimum of two weeks of severance pay for every year of service. This standard was met an average of only 10% of the time in the earlier reports.

In the latest report eight of the 12 employers met the standard of either making an effort to place terminees in other positions within the organization or helping them to find jobs elsewhere. For instance, all six Manville terminees who responded to a questionnaire stated that they received assistance in preparing resumes. Five of them also got help in actually finding a job and two also received retraining.

Compliance with the standard calling for full pension vesting after 10 years of service has always been high—an average of 79%. This time all 12 employers complied. In the layoff at Occidental Research Corp.,

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10-years' service.

Employee service. Those with minimum of 10-years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination at same rate of contribution as before. Employee would have additional 31-day grace period.

Rehire privileges. Rehire privileges should be carefully explained to terminees.

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employment dates were adjusted for terminees who were close to meeting the company's standard of fully vested pension rights after five "credited" years. Depending on the date of hire, this means as little as three years and seven months of service. At PPG Industries, fired employees who were over age 55 were entitled to receive an immediate or deferred pension benefit.

The PEG guideline states that such employees should not be terminated except for continued evidence of previously documented inadequate performance or cause. However, eight of the 12 firings covered in the new report involve those with more than 10 years of service—as do 72% of the terminations investigated earlier.

The sharpest turnaround in compliance has come in the standard that states that employee protection plans should be extended after termination for a minimum of one month, plus two weeks for each year of service, at the same rate of contribution as before. In the previous report all seven employers failed to comply. In the new report this standard was complied with in 11 of the 12 cases. In the Armak termination, group insurance plans were continued at company expense while severance pay was being paid. This continued until employees found jobs that provided coverage. After termination pay ran out, former employees could continue coverage for up to one year from their termination date by paying the company's group rate.

The seventh standard, concerned with rehire privileges, is complied with infrequently. In the new report only BASF Wyandotte met this standard. Also, at PPG Industries, terminees were told their qualifications would be reviewed when openings occur. □

Employer compliance with ACS guidelines

These employers provided information	Approximate number of terminees	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans	Rehire privileges
Akzona, Armak (Chicago, Ill.)[a,b]	16	■	□	□	□	▨	□	▨
Celanese (Corpus Christi, Tex.)[a,c]	17	□	▨	▨	□	□	□	▨
Celanese (Summit, N.J.)[a,c]	29	□	▨	□	□	▨	□	▨
Ethyl (Ferndale, Mich.)[a]	5	□	▨	▨	□	■	▨	▨
ITT Rayonier (Whippany, N.J.)[a,c]	34	□	▨	□	□	■	□	▨
Manville (Denver, Colo.)[a]	11	▨	□	□	□	▨	□	▨
Occidental Oil Shale (Grand Junction, Colo.)[a,b,c]	5	□	▨	▨	□	□	□	▨
Occidental Research (Irvine, Calif.)[a,c]	70	▨	□	□	□	▨	□	▨
PPG Industries (Corpus Christi, Tex.)[a,c]	26	□	□	□	□	▨	□	▨
These employers provided no information								
Air Products & Chemicals/ Stearns-Roger Engineering (Denver, Colo.)	4	■	■	▨	□	▨	□	▨
BASF Wyandotte (Parsippany, N.J.)	4	▨	□	□	□	□	□	□
Jim Walter Corp. (St. Petersburg, Fla.)	6	■	▨	□	□	□	□	▨

□ Employer met guideline standard

▨ Employer did not meet guideline standard

■ Employer was substantially below guideline standard

This is defined as follows:

- Advance notice—less than 2 weeks.
- Assistance—no assistance rendered.
- Severance pay—less than 1 week per year of service.
- Employee service—more than 40% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

a Rating on assistance based on information from the terminees. b Rating on protection plans based on information from the terminees. c Rating on severance pay based on information from the terminees.

Staff Associate

Office of Professional Training

The American Chemical Society is seeking a chemist who would like the challenge of being responsible for assisting in the administrative and technical support for the Society's national approval program of undergraduate chemistry departments, for publishing the ACS Directory of Graduate Research, and other special projects.

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EOE/MF

Biochemistry—a C&EN Science Update Page 18

JULY 4, 1983

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Salaries, unemployment both up moderately for chemists

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JULY 4, 1983

News of the Week

■ **An NAS study directly links acid rain to power plant emissions but admits the scientific data are too weak at present to clarify other pertinent questions.** **Page 6**

■ **Supreme Court's ruling allows states to tax the international income of U.S. firms that conduct business overseas.** **Page 7**

■ **Hercules will venture much further into the high-technology aerospace business by acquiring Simmonds Precision Products.** **Page 7**

Business

Chemical industry's second-quarter performance has surpassed most expectations; outlook for second half is even better. **Page 10**

Government

Congress has reached quick agreement on a budget resolution for fiscal 1984 and is moving fast on other issues. **Page 14**

Science

Biochemical research is making headway in solving previously intractable biological problems by using new methods. **Page 18**

Science Policy

Fresh ideas in science policy involving energy technology and innovation are put forth by right-wing think tank. **Page 25**

Technology

Newly developed zirconium catalysts are extremely active and accomplish rapid polymerization of olefins. **Page 29**

Education

Use of microcomputers in chemical education is being promoted by a National Science Foundation development project. **Page 30**

Books

Divergent views on the desirability of utilizing nuclear energy are presented in "Nuclear Power: Both Sides" by Michio Kaku and Jennifer Trainer. **Page 38**

Salary Survey

Chemists' unemployment was higher this spring than at any time since 1972; their salaries were only moderately above a year ago. **Page 33**

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Unemployment Highest Among Chemists Since 1972

Salaries make modest gain in past year, largely in step with cost of living, annual survey of ACS members indicates

For the second year in a row, unemployment has climbed perceptibly for U.S. chemists. As of last March, 2.2% of the chemists who are members of the American Chemical Society were jobless and looking for work, up from just 1.5% a year earlier. The unemployment rate for chemists this year is double what it was two years ago. Not since 1972, when unemployment among ACS chemists was 3.2%, has the rate been as high as 2%.

Other figures from the latest annual survey of the economic status of ACS members, conducted annually by the ACS Office of Manpower Studies, also point to a weaker job market this year for the chemical profession. The fraction of chemists employed full-time is lowest also since 1972, reflecting not only increased joblessness but also an increase among chemists working part time (1.6%, up from 1.4% a year ago) and those who are doing postdoctoral work (2.6%, up from 2.2% in March 1982).

Despite the increase, however, unemployment among chemists is relatively low compared to that of the nation's workforce overall. The unemployment rate of the U.S. civilian labor force peaked at 10.8% last December in the throes of the worst business recession since World War II. It had declined to 10.3% by March—and, with business clearly on the upswing this spring, to 10.1% by May.

Although the recession last year cost relatively few chemists their jobs, its impact probably was more widespread in affecting salaries, which for the second consecutive year rose only moderately. The median salary for Ph.D. chemists, for example, increased 7% to $40,000. (The median is the salary that is exceeded by 50% of the individuals responding to the ACS survey.) The increase during the past year for Ph.D.s is the same as that the year before but well below the 12% gain in median salary that they won between 1980 and 1981.

For chemists lacking a Ph.D., the increase in salaries during the past year was even less favorable. Salaries for those whose highest degree is a B.S. were 5% higher this year, at the median, than in 1982; they had been up 4% last year and 10% the year before that. For chemists with an M.S., the median was only 4% higher this

Although up this year, unemployment remains relatively low for ACS members . . .

	CHEMISTS									
		By sex		By highest degree			By minority status			
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	Chemical engineers	All ACS members[c]
Employed full time	92.4%	93.6%	85.0%	93.5%	93.6%	91.5%	88.8%	92.7%	92.0%	92.1%
Employed part time	1.6	1.1	4.5	1.5	2.2	1.5	1.5	1.6	1.6	1.7
Postdoctoral or fellowship	2.6	2.3	4.4	0.3	0.6	4.3	6.0	2.3	0.5	2.2
Unemployed										
Seeking employment	2.2	2.0	3.3	3.1	2.1	1.8	3.3	2.1	3.2	2.5
Not seeking employment	1.2	0.9	2.8	1.6	1.5	0.9	0.5	1.3	2.7	1.5

a As of March 1, 1983. b Black, American Indian, Alaskan native, Asian or Pacific, Hispanic, or other. c Includes members whose highest degree and present work are in neither chemistry nor chemical engineering. Source: ACS survey

. . . but salaries increased only moderately from the year before

											Annual change		
$ Thousands	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1982–83	1978–83	1973–83
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$30.0	$28.5	$27.5	$25.0	$23.5	$22.0	$21.0	$19.8	$19.0	$17.5	$16.8	5%	6%	6%
M.S.	33.0	31.6	30.0	26.0	25.0	24.0	22.0	20.5	19.8	18.4	17.5	4	7	7
Ph.D.	40.0	37.5	35.0	31.2	29.0	27.4	26.0	24.7	23.0	21.7	20.5	7	8	7
All chemists	36.0	34.7	32.0	28.9	na	na	na	na	na	na	na	4	na	na

a As of March 1, 1983. na = not available. Source: ACS survey

At some experience levels, salaries of chemists in top 10% are double those in bottom 10%

Years since B.S. degree	0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
	Annual salaries of nonacademic chemists ($ thousands)[a]										
B.S.											
90%	$27.5	$28.6	$34.0	$40.1	$49.1	$52.4	$60.0	$60.0	$57.3	$64.8	$50.0
75%	23.2	25.0	30.0	35.0	40.5	44.4	49.4	49.0	46.8	52.6	39.7
Median	20.0	22.0	25.8	30.0	35.0	38.0	41.0	40.0	39.0	43.0	30.0
25%	15.5	19.1	22.0	25.5	28.0	31.2	33.0	34.0	32.0	35.0	24.0
10%	14.0	16.0	19.0	21.6	23.9	25.6	26.4	26.6	28.1	26.1	20.0
M.S.											
90%	—	29.0	35.0	41.8	50.1	55.0	62.0	58.6	70.0	60.0	52.0
75%	—	27.0	31.8	37.0	43.0	44.8	50.0	50.8	50.6	46.2	43.0
Median	—	24.5	27.0	31.2	35.3	39.3	42.9	42.0	41.7	38.2	35.0
25%	—	21.0	23.5	27.0	30.8	33.1	35.1	36.0	35.0	29.9	28.0
10%	—	18.4	20.0	23.9	26.3	28.5	27.0	30.4	29.8	24.0	23.0
Ph.D.											
90%	—	—	40.0	48.2	58.0	65.0	70.0	72.0	76.5	72.0	65.0
75%	—	—	37.6	43.0	50.0	55.8	60.0	62.0	64.2	59.0	53.3
Median	—	—	34.8	38.0	43.0	48.0	50.9	52.8	53.6	46.0	44.0
25%	—	—	32.6	34.5	37.5	41.0	44.2	45.0	44.0	38.4	36.9
10%	—	—	30.0	31.0	32.0	35.6	36.4	37.8	38.0	33.0	32.3

a As of March 1, 1983. **How to read this table:** Using, as an example, B.S. chemists two to four years after having received their B.S. degree: 90% of these chemists have annual salaries of $28,600 or less, 75% have salaries of $25,000 or less, 50% have salaries of $22,000 or less, 25% have salaries of $19,100 or less, and 10% have salaries of $16,000 or less, as of March 1, 1983. **Source:** ACS survey

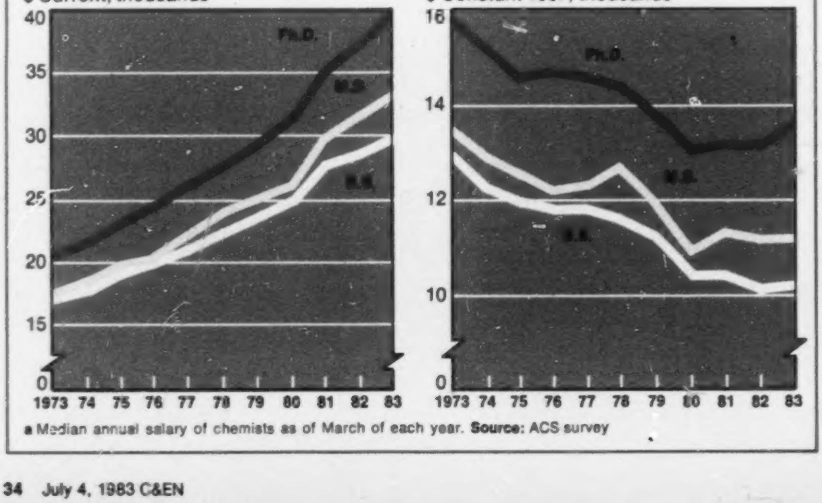
year, following a 5% rise in 1982 and one of 15% in 1981.

Inflation, however, has moderated considerably during the past year or so. Consequently, the long erosion in the purchasing power of chemists' salaries over the past decade finally appears to have eased. Consumer prices increased slightly less than 4% between March 1982 and March 1983. In constant dollars, therefore, Ph.D. chemists this year are 3% better off than they were a year ago, while chemists with lesser degrees just about held their own. Even so, after factoring in the effect of inflation, chemists salaries are 15 to 20% lower than they were 10 years ago. In fact, they are about at the same level as they were two decades ago.

The median salary provides only a very broad-brush indication of what an individual chemist's salary is likely to be, of course. Experience, employer, and type of work performed all are important factors affecting the level of earnings.

Chemists working in industry, for example, typically have higher salaries than those teaching in colleges or universities. Thus, the median salary for a Ph.D. doing research in industry, at any given level of experience, is higher than that of a chemistry professor in a Ph.D.-granting college or university and higher still than that for a professor teaching at a school that does not offer a Ph.D. in chemistry. For example, the median salary for Ph.D. chemists working at applied research in industry, 20 to 30 years after having received their B.S. degree, is roughly 10% greater than that of a full professor who has been out of undergraduate school for a similar length of time. Compared to a full professor in a non-Ph.D.-granting school, the industrial researcher has a median salary nearly 50% higher.

In industry, moreover, chemists who have moved into management positions—either in management of research and development or general management—typically have higher salaries than those directly involved with research and development. And industrial chemists to whom few or no subordinates report earn appreciably less than those to whom several people report. Thus, the 30% of industrial chemists who supervise nobody have a median salary that is less than half that of the 3% who su-


The increase in chemists' salaries during the 1980s . . .

. . . has been largely wiped out by inflation

a Median annual salary of chemists as of March of each year. **Source:** ACS survey

Differences between salaries of men and women is narrowest for government chemists

Mean salary, $ thousands[a]	B.S.				M.S.				Ph.D.			
	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men	All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	$34.7	$35.4	$30.0	85%	$38.2	$39.0	$32.8	84%	$47.7	$47.9	$41.2	86%
College/university	—	—	—	—	—	—	—	—	33.7	34.1	28.6	84
Government	30.7	31.5	26.7	85	—	—	—	89	43.3	43.5	40.0	92
Other nonacademic	28.9	29.8	24.5	82	—	—	—	—	—	—	—	—

a As of March 1, 1983; to facilitate comparison, salaries are adjusted for differences in the average experience for each group. **Source:** ACS survey

Salaries of industrial chemists are highest in the oil industry

Industry	% of industrial chemists				Mean salary ($ thousands)[a]		
	All chemists	B.S.	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Chemical	31%	25%	27%	37%	$35.0	$39.1	$47.4
Pharmaceutical	18	16	21	18	32.3	35.0	48.0
Petroleum	7	6	5	8	37.0	45.5	54.2
Coatings	6	9	7	4	33.5	37.6	44.7
Food	4	5	4	3	31.1	39.5	46.0
Metals and minerals	3	4	3	2	31.3	38.2	43.2
Rubber	2	4	3	1	35.5	38.4	46.2
Paper	2	1	2	2	30.6	33.0	43.1
Other manufacturing	20	22	21	19	33.1	37.4	46.1
Nonmanufacturing	6	8	8	5	28.5	36.4	46.4

a As of March 1, 1983; to facilitate comparison, salaries are adjusted for differences in the average experience for each group. **Source:** ACS survey

Salaries are highest for chemists who supervise

Number of subordinates	Median annual salaries,[a] chemists in private industry ($ thousands)			
	All chemists	B.S.	M.S.	Ph.D.
ALL SUBORDINATES				
0	$31.2	$25.0	$30.7	$39.3
1–2	38.0	32.0	35.0	40.5
3–7	40.0	35.0	36.0	45.0
8–12	45.0	37.8	40.5	49.2
13–17	49.0	39.8	45.8	52.0
18–22	52.3	40.0	49.0	56.0
23–32	52.0	45.2	45.2	55.0
33–47	60.0	52.0	56.0	65.0
48–67	60.0	55.0	54.5	65.0
68–99	72.0	68.5	—	72.3
100 or more	70.0	65.0	60.0	74.3
PROFESSIONALS AND TECHNICIANS ONLY				
0	$32.0	$25.7	$31.0	$40.0
1–2	37.8	31.6	34.4	40.5
3–7	40.5	35.0	36.8	45.4
8–12	47.0	41.0	44.0	50.0
13–17	49.7	40.0	45.6	53.4
18–22	52.6	48.2	45.0	55.0
23–32	54.0	42.5	49.0	60.0
33–47	62.0	56.7	57.0	65.0
48–67	65.0	73.0	—	65.2
68–99	70.0	—	—	72.6
100 or more	73.6	—	55.0	75.8

a As of March 1, 1983. **Source:** ACS survey

pervise 50 or more people and roughly two thirds or less that of the 10% who have 20 or more people working for them. Age and experience probably are factors, of course, because the chemists who have greater managerial responsibilities are also likely, as a group, to be older than those with little or no supervisory duties.

The industry in which a chemist works also is a factor influencing earnings. Median salaries tend to be highest, as in the past, in the petroleum industry, where 7% of all industrial chemists work. Salaries are next highest in the chemical industry, which employs 31% of industrial chemists, for those with a B.S. or M.S. degree; for chemists with a Ph.D., the chemical industry ranks third, slightly behind the pharmaceutical industry, in salary level.

As in the past, chemical engineers responding to the annual ACS survey report salaries appreciably higher than those of chemists. For chemical engineers with no more than a B.S. degree, the median salary is $40,000 as of last March, a third higher than the median for B.S. chemists. Engineers with an M.S. had a median salary of $41,900, 27% above that of their chemist counterparts. Those with a Ph.D. report a median of $48,500, a little more than 20% above the median for chemists holding a Ph.D.

The two groups actually are not comparable, however. Because of the makeup of ACS membership, survey respondents who are engineers tend to be older and more experienced than those who are chemists. They are a relatively small fraction, as well—accounting for only 8% of the total survey sample—and one containing fewer women (nearly less than 5%) than is the case with chemists (14% of whom are women). According to a survey made among its members by the American Institute of Chemical Engineers, the median salary for all chemical engineers in 1982 was $39,000, compared to $42,000 for all chemical engineers responding to the 1982 ACS survey of its members. That's 12% higher than the 1982 median salary for all chemists of $34,700.

Results from this year's ACS survey indicate no change in median salaries from last year for chemical engineers whose highest degree is either an M.S. or a B.S. (The median for Ph.D. engineers this year was up 8% from 1982). This rather surprising result can be explained in part, however, by a difference in the sample responding to this year's survey compared to the 1982 survey sample. Chemical engineers responding to the 1983 survey are younger, on average, and this shift in age distribution causes the 1983 data for chemical engineers to be not fully

Salaries tend to be highest for chemists if they are men and if they are managers

Years since B.S. degree		Median salary of chemists ($ thousands)[a]										
		0–1	2–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	≥40	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	$20.4	$22.6	$27.3	$31.2	$37.0	$39.9	$43.0	$40.0	$40.0	$43.0	$33.0
	M.S.	—	24.3	28.0	32.0	38.0	40.2	46.0	43.2	44.0	45.0	37.0
	Ph.D.	—	—	35.0	39.1	44.6	50.0	52.0	55.0	54.0	57.0	45.0
Women	B.S.	20.5	22.4	23.0	26.5	27.0	31.8	(26.4)	35.0	36.0	(38.0)	24.5
	M.S.	—	25.0	25.0	31.5	31.4	(40.9)	(30.0)	(36.0)	(33.1)	—	29.0
	Ph.D.	—	—	35.0	37.2	39.0	40.4	(43.0)	—	—	—	36.8
Work function												
General management	B.S.	—	25.6	31.5	37.5	44.8	50.0	48.6	55.0	45.0	—	40.0
	M.S.	—	—	(32.0)	40.0	45.0	48.0	56.0	54.4	—	—	48.0
	Ph.D.	—	—	—	(45.0)	50.0	62.8	50.6	56.8	(55.0)	(63.0)	55.0
R&D management	B.S.	—	(24.3)	34.0	34.3	40.0	42.2	45.0	49.0	44.0	50.0	41.0
	M.S.	—	—	34.2	38.5	48.0	44.3	50.5	50.0	(52.5)	50.0	45.0
	Ph.D.	—	—	(38.0)	43.9	49.0	52.0	59.5	65.0	60.0	68.0	53.0
Basic research	B.S.	21.5	22.9	25.0	28.8	(29.3)	(28.5)	33.7	(31.0)	—	—	25.0
	M.S.	—	(25.0)	27.0	30.0	34.0	34.5	—	—	(51.0)	—	31.0
	Ph.D.	—	—	35.0	36.5	43.0	53.4	50.5	44.0	54.0	60.0	40.1
Applied research	B.S.	22.0	22.6	26.4	30.0	35.8	39.2	40.5	39.5	40.2	41.1	29.5
	M.S.	—	27.0	27.0	30.0	33.2	40.0	43.5	39.9	(40.0)	41.5	32.5
	Ph.D.	—	—	34.5	37.0	41.6	45.2	48.0	50.0	49.0	46.0	41.0
Work specialty[b]												
Agricultural chemistry	B.S.	—	20.5	24.0	34.0	38.5	40.0	—	41.1	(35.0)	(40.0)	32.9
	M.S.	—	—	—	(34.0)	(30.3)	(44.0)	(36.2)	(60.0)	—	(47.0)	37.1
	Ph.D.	—	—	33.0	35.4	41.0	48.0	(54.0)	52.0	—	(77.2)	42.3
Analytical chemistry	B.S.	18.7	23.0	25.8	28.2	36.0	34.0	40.0	39.5	40.4	45.4	28.3
	M.S.	—	24.7	27.9	30.5	36.2	37.5	42.9	40.0	39.0	(50.0)	34.0
	Ph.D.	—	—	34.3	38.0	42.2	48.0	47.3	56.8	54.0	47.2	40.7
Biochemistry	B.S.	—	22.0	23.2	—	—	—	—	—	—	—	24.0
	M.S.	—	—	(23.6)	—	—	—	—	—	—	—	30.0
	Ph.D.	—	—	(34.5)	37.0	39.9	(48.4)	52.9	61.5	(66.2)	(82.0)	41.8
Chemical engineering	B.S.	(26.3)	27.0	32.7	37.2	40.4	52.6	53.0	46.0	48.0	49.9	40.0
	M.S.	—	(32.0)	32.7	37.0	41.2	55.0	46.7	55.0	49.2	55.0	42.0
	Ph.D.	—	—	39.8	43.8	50.0	55.3	59.0	55.8	54.8	65.0	50.0
Environmental chemistry	B.S.	—	24.0	27.8	28.5	38.3	(39.0)	—	38.9	(32.0)	—	30.8
	M.S.	—	—	27.6	34.6	38.3	(41.0)	(42.3)	(36.0)	—	—	36.0
	Ph.D.	—	—	—	42.0	46.0	50.0	(46.0)	(50.0)	(51.8)	—	47.0
Inorganic chemistry	B.S.	—	(23.0)	26.2	33.0	—	(32.3)	50.0	44.0	—	—	31.4
	M.S.	—	—	(32.4)	(32.4)	—	—	(51.5)	(45.8)	—	—	40.4
	Ph.D.	—	—	35.0	39.6	42.6	52.0	(46.0)	(60.2)	—	(61.0)	41.4
Organic chemistry	B.S.	(22.2)	21.8	28.0	30.5	36.0	44.9	52.0	35.0	45.0	47.3	35.0
	M.S.	—	(22.0)	27.0	30.8	33.0	39.6	50.0	45.2	(46.5)	44.0	38.0
	Ph.D.	—	—	35.0	37.0	45.0	49.5	52.0	58.0	50.5	64.5	44.8
Pharmaceutical chemistry	B.S.	17.5	21.8	25.4	30.0	31.0	33.0	38.3	42.0	—	—	27.3
	M.S.	—	—	25.8	31.0	32.4	41.2	(35.5)	(40.0)	—	(45.0)	31.0
	Ph.D.	—	—	34.2	40.0	45.0	52.0	60.0	54.0	68.0	59.0	45.0
Physical chemistry	B.S.	—	—	—	—	—	(44.2)	—	(40.0)	—	—	38.0
	M.S.	—	—	(31.0)	—	(47.0)	—	—	(43.0)	—	—	36.2
	Ph.D.	—	—	37.0	40.5	45.6	49.0	52.3	49.5	54.0	56.5	45.0
Polymer chemistry	B.S.	20.1	23.0	27.0	33.2	37.8	40.0	44.5	47.0	40.6	43.0	34.0
	M.S.	—	(28.3)	30.9	34.3	35.5	42.2	42.0	44.5	44.5	39.5	37.4
	Ph.D.	—	—	35.0	41.0	45.0	50.0	54.5	56.5	55.0	51.0	46.0
CHEMISTS EMPLOYED FULL TIME IN ACADEMIC (Ph.D.s ONLY)												
Ph.D.-granting schools												
Professor		—	—	—	—	40.0	40.0	44.0	42.3	47.2	49.0	44.0
Associate professor		—	—	—	28.6	34.0	32.6	31.0	32.5	(33.0)	(42.0)	32.0
Assistant professor		—	—	23.6	25.0	24.3	25.9	(22.0)	—	—	—	25.0
Non-Ph.D.-granting schools												
Professor		—	—	—	—	28.5	30.7	32.0	32.0	32.7	33.0	31.3
Associate professor		—	—	—	21.5	24.5	26.0	29.5	25.3	—	—	25.0
Assistant professor		—	—	19.4	20.0	20.0	(20.7)	—	—	—	—	20.0

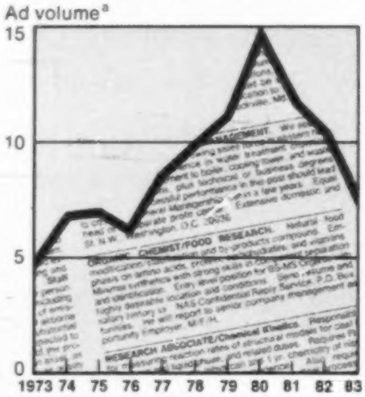
a As of March 1, 1983. b Refers to current work, not field in which degree was obtained. **Note:** Where no salary data are shown, sample is too small to provide meaningful figure; data in parentheses are from relatively small samples as well and should be treated with caution. **Source:** ACS survey

Joblessness for chemists highest in past decade

Employment status[a]	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Employed full time	93.5%	94.9%	95.6%	95.9%	95.0%	95.7%	95.4%	94.7%	95.0%	95.1%
Employed part time	1.7	1.4	1.1	1.0	2.0	1.0	1.1	1.3	1.3	1.0
Postdoctoral or fellowship	2.6	2.2	2.2	2.2	1.9	1.9	2.1	2.2	2.0	2.5
Unemployed	2.2	1.5	1.1	0.9	1.1	1.4	1.5	1.9	1.6	1.4

[a] As of March 1; excludes unemployed chemists not seeking employment. **Source:** ACS survey

Volume of help-wanted ads down sharply since 1980



[a] Volume of help-wanted advertising (in thousands of column inches) in C&EN for the 12 months ending with May of each year.

Unemployment lowest in government, academia

	% in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	61%	2.4%
College/university	24	1.5
Government	9	1.2
Other	6	3.8
MOST RECENT WORK FUNCTION		
R&D	37%	1.9%
Teaching	25	1.6
Management[b]	18	1.9
Marketing, production	12	3.0
Other	8	4.1
MOST RECENT WORK SPECIALTY		
Analytical	20%	2.4%
Organic	16	2.2
Polymer	12	2.8
Pharmaceutical	9	2.2
Biochemistry	8	1.3
Physical	8	2.0
Inorganic	6	1.4
Environmental	6	3.0
Agricultural	4	1.9
Other	10	2.4

[a] As of March 1, 1983; excludes unemployed chemists not seeking employment. [b] Includes R&D management. **Source:** ACS survey

comparable with the 1982 data. Adjusting the 1983 mean (rather than median) salaries for chemical engineers to account for the difference in age distribution with last year indicates that overall salaries for chemical engineers with a B.S. are 4% higher and for those with an M.S. are 9% higher than the year before.

Overall, salaries for men continue to be greater on average than those paid to women. This year, in fact, the gap appears to be a bit wider than it was in 1982, at least for B.S. and Ph.D. chemists, after the raw data are adjusted for differences in years of experience between the two sexes. (In the overall survey sample, women as a group are younger than men.) Thus, on an age-adjusted basis, in industry women with a B.S. have a mean salary 85% that of men with a B.S.; last year their mean was 88% that of men. For Ph.D.s working in industry, the women's mean is 86% that of men this year, down from 96% the year before. Among Ph.D.s teaching in colleges and universities, the mean for women is 84% that for men this year, down from 89% in 1982.

As has been the case in recent years, the difference between salaries earned by men and women is small or nonexistent early in their careers. The median for men in industry with a B.S. obtained two to four years ago is $22,600; that for similar women is $22,400. The median is $35,000 for both men and women in industry who have a Ph.D. earned after obtaining a B.S. five to nine years ago. On the other hand, men in industry with a B.S. granted 20 to 24 years ago have a median salary that is 25% higher than women in the same category.

Women also are more likely to be jobless than men. This year, 3.3% were unemployed but seeking work, up from 2.8% in 1982 and 2.4% in 1981. Among men, 2.0% were similarly unemployed this year, up from 1.3% in 1982 and 0.9% in 1981. And although the unemployment rate is higher generally across the board, chemists with no more than a B.S. are more likely to be seeking work than those with an advanced degree. In the academic world, the unemployment rate is less than 1% for faculty other than instructors, for whom it is 4.6%.

But the worst may be over as far as the job market for chemists is concerned. Business clearly is improving now for the chemical industry. And classified employment advertising in C&EN, the leading U.S. outlet for such advertising aimed at chemists, also shows tentative signs of an upswing. The volume of help-wanted ads in C&EN had fallen erratically since it peaked about three years ago and hit a 10-year low last summer. It then recovered moderately last fall and winter, but turned down once more this spring. More recently, however, it has been increasing again, although to a level only about half of what it was early last year. It is still too early to judge how prolonged or substantial the rebound may be.

These data on employment and salaries for ACS members are based on more than 12,000 responses to a mail survey carried out during March by the Office of Manpower Studies of the ACS Department of Professional Relations & Manpower Studies. The survey was made only among members who are 70 or younger, have a U.S. mailing address, are not retired, and are neither of student or emeritus status.

A full report on the annual survey, carrying much more detailed statistics than reported here, is being published this month. The report, "Salaries 1983," can be purchased at $60 per copy from the Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. □

JULY 11, 1983

CHEMICAL & ENGINEERING NEWS

FINAL PROGRAM
ACS Washington, D.C., meeting
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Linus Pauling wins 1984 Priestley Medal

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Cover: Photo by C&EN's Rudy Baum

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CHEMICAL & ENGINEERING NEWS

JULY 11, 1983

News of the Week

- **Two developments concerning agent orange—release of evidence in suit against producers and of an Air Force mortality study—add to understanding of dioxin danger. Page 4**
- **Study on the health effects of exposure to chemicals in hazardous waste sites is planned by Chemical Manufacturers Association. Page 5**
- **Newly approved use by FDA of low-calorie sweetener aspartame in carbonated diet soft drinks raises cost questions. Page 5**

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Business

Lime, sulfur, potash, and phosphorus hurt by low demand for use in fertilizer, steel, and detergent markets. **Page 7**

Government

Legislative veto, ruled as unconstitutional, could affect the chemical industry through such laws as Superfund. **Page 13**

Science

Dioxin's health risk being examined by EPA, other groups; EPA's dioxin research budget nearly triples. **Page 16**

Science Policy

U.S. role in industrial science and technology policy is under scrutiny in study by the American Enterprise Institute. **Page 21**

Final Program

The 1983 ACS annual meeting in Washington, D.C., boasts 516 technical sessions, features a variety of social activities, special events, and awards. **Page 28**

Priestley Medal

Linus Pauling, man of controversy and distinction, discusses his interest in molecular structure, contributions to chemistry, and penchant for new ideas. Page 18

Mineral-Based Inorganics Languish in Continuing Recession

It's still tough times for lime, sulfur, potash, and phosphorus because demand continues low in fertilizer, steel, and detergent markets

Bruce F. Greek, C&EN Houston
William F. Fallwell, C&EN Washington

The major U.S. mineral-based inorganics, such as the four covered here—lime, sulfur, potash, and phosphorus—seemed to bob up in the late 1970s and show new life after earlier shocks. But the 1980s have been rough sledding. Even though they are not hydrocarbon-based and thus somewhat buffered from the world oil price, these materials are in deep trouble.

It isn't just that these products have been caught in the recession and are slow in recovering. That's certainly true and explains much of the combined 20% tonnage drop last year. However, there are deeper market fissures that will remain even if these inorganics get some lift from the general economic recovery.

Part of the underlying problem is that these inorganics are textbook commodities. Three of them—lime, sulfur, and potash—are ultracheap, low-value-added materials going to highly mundane uses wide open to competition worldwide. As many other commodity chemical producers have found out lately, that's a very dangerous position for old products in an industrialized economy. Phosphorus is notably higher priced but still suffers from many of the same commodity blues.

As a result, all of the traditional U.S. sources of these chemicals are slowly losing out to newer developments, many hinging on international trade. Take lime, with the largest volume of the four and one of the highest-tonnage products of the entire chemical industry. Although foreign trade in lime itself is miniscule, trade has hurt its major outlet in steel horribly.

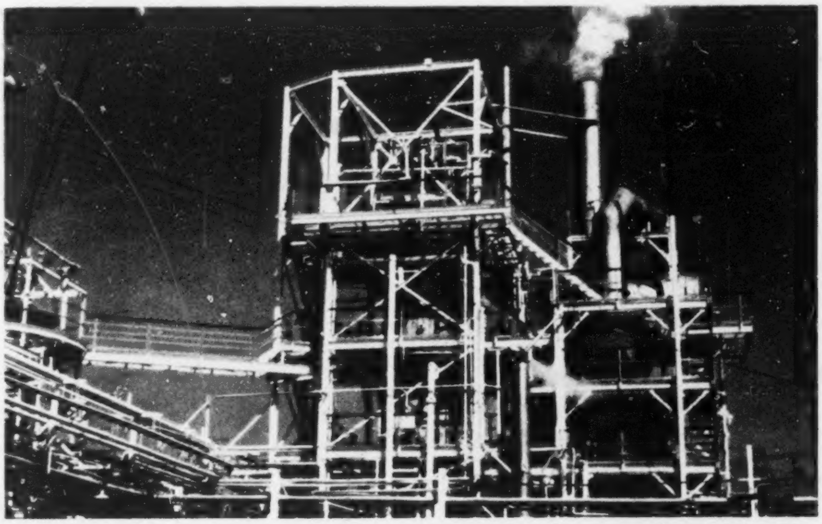
Then in sulfur, conventional mined (Frasch-process) production is essentially priced out of the market by newer by-product sources stemming from pollution control installations at oil refineries, natural gas processing plants, and metals smelters. As yet, there isn't enough by-product capacity to wipe out Frasch production, but Frasch output is definitely the swing part of supply and goes up and down dramatically with economic cycles. Here, too, imports of by-product sulfur are now a major part of supply.

Key Chemicals

For potash, Canadian imports are the crucial problem and have pushed down U.S. production by half over the past two decades. Although U.S. potash steadied itself in the late 1970s and had some good years, it is sinking fast at the moment. U.S. potash capacity is down about one fourth from three years ago, exports have dropped in half, and output is off one third. The crowning blow has come from the U.S. government, whose payment-in-kind (PIK) program to reduce planted acreage has crimped most agricultural chemicals this year.

Phosphorus is a much higher-value product than the other three—its total production value, for example, is more than three times that of potash and 125% of that of lime, even though phosphorus tonnage is a small fraction of the other two. That still doesn't save phosphorus from competition. As competing wet-process phosphoric acid is made in purer grades, one after another of elemental phosphorus markets is threatened.

For details on the sobering immediate market prospects for these chemicals, see the following pages.



Furnace at FMC's Carteret, N.J., plant converts phosphorus to phosphoric acid

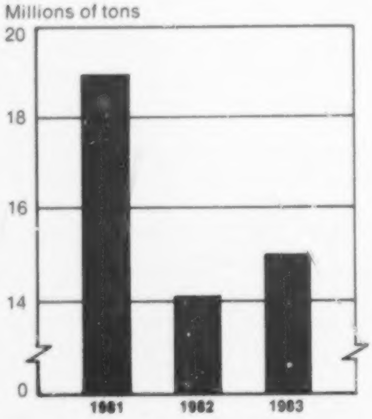
Key Chemicals

Lime

CaO

- ***Limited demand recovery***
- ***Capacity too large***
- ***Pricing still weak***

PRODUCTION



Note: No capacity estimates are available.

HOW MADE

Calcining limestone (mainly $CaCO_3$) make quicklime (CaO), then adding water to make hydrated lime ($Ca(OH)_2$)

MAJOR END USES (U.S.)

Metallurgy (mainly steel flux) 40%, chemicals 10%, potable water treatment 10%, sewage and pollution control 10%, construction 5%

FOREIGN TRADE

Exports—about 25,000 tons in 1983, imports—flat at about 350,000 tons

PRICES

$30 to $50 per ton, depending on type; discounts still significant

COMMERCIAL VALUE

$550 million for production, 1983

Lime, the fifth-largest-volume chemical produced in the U.S., faces a long road back after an extraordinarily rough trip through the past three recessionary years. Normally a slow-moving product with a 20-year history of steady rise and then plateau, lime was smashed three years straight for a net 33% production drop after its recent high point of 21.0 million tons in 1979. Last year alone, lime output fell 25% to 14.1 million tons.

Recovery from this disastrous period has just begun, considerably behind recovery of many other chemicals, some of which use lime in their manufacture. In first-quarter 1983, lime production apparently still declined, about 10% from first-quarter 1982.

However, for all of 1983, lime production likely will rise 5% or more. Steel making, the largest use for lime, has been rising from its extreme low point late last year and appears to be pulling lime up with it.

If steel demand doesn't falter, if most of the other shell-shocked uses of lime recover, and if lime's lone rising use in stack gas scrubbing keeps going, lime production could exceed 15 million tons in 1983, up 7%.

There is some seasonality in lime demand, with more consumed in the second half of the year than in the first. The reasons include variations in steel demand related to shifts in automobile production and vagaries in small uses such as sugar beet processing. In 1982, such seasonality didn't appear, mainly because of steel's abysmal fourth quarter, when operating rates plunged to 30 to 35% of capacity.

Estimates of total lime use in metallurgy last year fell to about 4.8 million tons, down a whopping 39% from 7.9 million tons in 1981. Steel accounts for more than three fourths of this market, whose share of total lime use sank to just 34% in 1982, down from 42% in 1981. Assuming continued, although slowing, improvement in steel operations, combined with some gains in copper use, the metallurgical outlet could rise again to nearly 40% of lime use this year.

The shift over the past two decades to basic oxygen and electric furnaces for making steel caused a large overall increase in lime consumption until this recent economic downturn. However, this shift away from old open-hearth furnaces has been just about completed. Some lime makers can't expect more penetration growth in that use and will have to follow steel demand more directly. One slight advantage for lime is that, in periods of slow demand, the newer, lime-using furnaces are run preferentially. Still, lime could suffer if steel imports continue their rapid inroads.

In 1982, the only major use of lime that increased was stack gas scrubbing for pollution control. That use reached more than 1 million tons, or 7% of production. In 1983, the scrubbing outlet likely will post another record, probably up more than 10%, according to industry analysts. This area likely will continue to grow fairly fast as more scrubbers are installed, especially on industrial boiler stacks, which are now quite a small market compared to electric power plants. The power plant use could jump again if the current wave of reports on the acid rain controversy produces Congressional action.

The other major end uses of lime declined in 1982. They all seem likely to turn around in 1983, but many may not recover to 1981 levels. For example, construction uses, spurred by soil stabilization needs, could show one of the better gains this year as monies from the increased federal gasoline tax start pouring into highway construction and repair.

No significant changes in swollen lime capacity will occur in 1983. Many lime plants have been shut down and likely will remain down for a long time. Because of the uncertainty over which plants might still be operable long term, capacity estimates for lime are considered meaningless.

About 75% of currently operating plants are throught to be fueled by coal, whose cost increased little in 1982 and may not increase much this year either. Further conversion to coal seems likely in plants now shut down as a way to boost competitiveness if restarted.

Even with such economies and slowing rising levels of plant use, lime faces another difficult year. Its only market area with basic growth is stack gas scrubbing, and its biggest use in steel faces a shaky future.

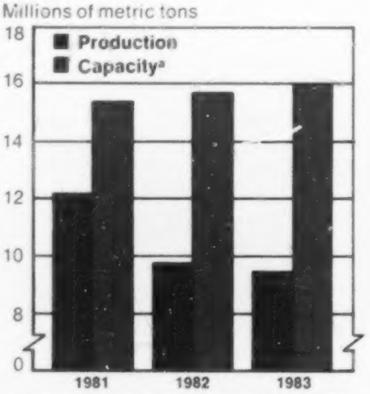
Key Chemicals

S

Sulfur

- ***Demand down***
- ***Capacity inching up***
- ***Prices lowered***

PRODUCTION/CAPACITY



[a] All sources as of first quarter, exclude standby capacity of about 5 million metric tons at recovery plants and smelters.

HOW MADE

Melted from underground deposits; recovered from sulfur compounds processed in refineries, natural gas processing plants, and smelters

MAJOR DERIVATIVES (U.S.)

Sulfuric acid 90%, chemicals 5%

MAJOR END USES (U.S.)

Fertilizer 60%, chemicals 20%

FOREIGN TRADE

Exports—down slightly to 850,000 tons in 1983, imports—down to about 1.7 million tons

PRICES

List price at Tampa, Fla., $132 per ton; discounts offered in addition

COMMERCIAL VALUE

$1.1 billion for production, 1983

Sulfur was quite late joining the U.S. business slump of the past three years, and it will again be way behind the rest of the chemical industry in recovering. In fact, sulfur production could drop a bit more in 1983 after a 19% plunge last year.

So the yellow element remains in turmoil. Forced increases in production of by-product sulfur from pollution control units at oil refineries and metals smelters have wreaked havoc for mined (Frasch) sulfur production, which nosedived 34% last year.

The main problem is a suddenly constricted fertilizer business, sulfur's dominant market force. Farmers around the world are having financial problems, and now the U.S. government, in a rescue attempt, temporarily has made things worse for fertilizer suppliers. Sulfur will be one of the chemical raw materials most affected by the government's payment-in-kind (PIK) program designed eventually to increase farm commodity prices by holding down current crops. Even though sulfur seems a long way from corn, wheat, and cotton and actually never reaches them as such, its derivative chain through sulfuric acid and phosphate fertilizer hangs mostly on these crops.

Since fertilizer exports also have suffered, analysts see dim prospects for a full recovery in sulfur demand in 1983. The most optimistic view calls for sulfur production to match 1982 at 9.8 million metric tons, counting all forms of production—Frasch, recovered, smelter acid, pyrites, and other. Pessimists don't see it that way and look for much lower production of about 9 million metric tons, especially if forecasts for sulfur imports prove too low.

All these forecasts have many chances to err, both camps admit. Besides the difficulty in estimating the net of imports over exports (both large), this year the economic recovery could further upset forecasts. For example, if industrial demand for sulfuric acid proves higher than expected and fertilizer inventories begin building later in 1983 in anticipation of better farm income, then sulfur production could be much higher. Strong recovery also could upset forecasts for relatively low smelter acid production of sulfur or sulfuric acid, should demand for copper and zinc rise rapidly because of depleted inventories.

Offsetting these brighter possibilities are contrasting factors, such as higher interest rates that might dampen fertilizer inventories, greater foreign competition for export fertilizer sales intensified by the strong dollar, and less than favorable final results in the PIK program.

The midrange view is that 1983 sulfur production could drop 500,000 tons or more below 1982. Monthly data from the Bureau of Mines for Frasch and recovered sulfur production (but not including other forms, which account for about an eighth of the total) are running 10% behind 1982 for the first four months of 1983. Making up this slump during the rest of 1983 may not be possible.

Should sulfur production fail to turn up in 1983, recovered sulfur production again might exceed Frasch production. In 1982, recovered sulfur exceeded Frasch production for the first time, taking 45% of the total, compared to 43% for Frasch. Even if recovered sulfur doesn't actually exceed Frasch in 1983, the longer-term trend will be for recovered sulfur to dominate production because it must be produced whether the market needs it or not. Almost all sulfur in the recovered category comes from oil refining and natural gas processing. Since crude oil is averaging a higher and higher sulfur content, recovery operations at refiners will continue to grow at the expense of Frasch sulfur, now considered as swing production.

Sulfur capacity is still growing, mainly in the recovered area. For example, new recovery units capable of producing 1000 tons a day of sulfur are coming on stream in the recently developed Overthrust Belt gas fields in Wyoming. Although these plants may not run at capacity for some time because of less than anticipated demand for the natural gas, they have the potential of adding large quantities to U.S. sulfur supply in the next few years.

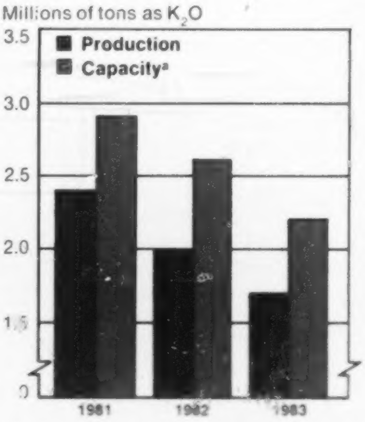
This additional capacity to produce sulfur continues to pressure prices, which have trended down this year. Financial relief is nowhere in sight, and sulfur's total value is due to yet another pasting, down about 25% from its 1981 peak.

Potash

KCl, K_2SO_4, $K_2SO_4 \cdot 2MgSO_4$

- ***Demand way down***
- ***Capacity slashed***
- ***Prices flat***

PRODUCTION/CAPACITY



[a] First quarter

HOW MADE

Shaft and solution mining of potassium salts, mainly the chloride, and subsequent purification

MAJOR END USES (U.S.)

Fertilizer 95%

FOREIGN TRADE

Exports—holding at about 400,000 tons in 1983, imports—rising to about 5.3 million tons

PRICES

\$110 to \$130 per ton of K_2O equivalent

COMMERCIAL VALUE

\$200 million for production, 1983

The U.S. potash industry has fallen badly in the past three years and is now the most troubled of the major mineral-based inorganics. The industry this year will be down to half size compared to its heyday in the mid-1960s. Canadian imports, which used to split the market, now command as much as 80% of it. U.S. exports are slumping, and U.S. capacity is fast shutting down. Altogether a very grim picture.

Unless something quite unexpected happens to pep up fertilizer use this fall, U.S. potash production will drop another 15% in 1983 to 1.7 million tons (measured as K_2O). This comes after a 17% decline in 1982 to 2.0 million tons. So potash is ailing at close to about one third under its steady output rate of about 2.5 million tons through the 1970s.

Actual U.S. potash demand this year may be about 6.5 million tons, down a bit. Obviously, imports are swelling and take care of most U.S. needs. Imports in 1982 supplied more than 70% of U.S. consumption, according to Bureau of Mines estimates, up from around 65% in 1981 and earlier years. This year, imports of perhaps 5.3 million tons may fill up to 80% of demand.

About a quarter of U.S. potash production will be exported in 1983. On its face, this looks odd in view of Canadian export strength. The explanation comes in transportation costs. Much of the U.S. farm belt can be served with less expensive freight from Canada than from U.S. potash production areas, mainly New Mexico. But potash from New Mexico does have a freight advantage to other areas, for example South American countries.

Even so, U.S. exports fell more than half in 1982 and are expected to remain at about that level, around 400,000 tons. Behind the decline are both debt problems in countries buying large quantities of U.S. potash in the past and relatively high prices resulting from the strong dollar.

U.S. potash fertilizer use declined in 1982 and is expected to be down a bit more in 1983 as a result of reduced acreage under the government's payment-in-kind (PIK) program. Because of this, combined with declining farm income and slumping exports, inventories rose roughly 40% in 1982 even with reduced production. These inventories, although somewhat reduced in early 1983, overhang the market now, keeping prices down and lowering production.

For the first four months of 1983, potash production declined about 17% from a year ago. A lower rate of decline is anticipated later in 1983 as inventories reach acceptable levels and possibly rebuild in advance of the 1984 planting season. Some improvement in production of potash could result from higher fall fertilization if farmers perceive beneficial effects from the PIK program.

If potash production reaches 1.7 million tons in 1983, existing nameplate capacity of about 2.2 million tons will run about 77%. This operating level probably will make a financial breakeven situation for most producers. Some producers who recover potash from western brines could have economic problems as a result of dilution from the heavy runoff after the large snow melt this year.

Another year of low or no profitability could lead to more U.S. mine and plant shutdowns, especially in the face of growing Canadian capacity and the slump in export markets. Alternatively, some facilities might be temporarily shut down over the next couple of years but not actually scrapped. They might be kept in operable condition and put back in production if demand recovers intermittently. Bookkeeping and taxes could help determine the outcome. Since early 1981, U.S. potash capacity has sunk 700,000 tons per year, or 24%, from its old total of 2.9 million tons.

An eventual upturn in U.S. potash will have to come in 1984 or later, depending on whether the PIK program is continued next year. If farm income does rise significantly this year, then sales of all kinds of fertilizer could be up in 1984. Potash might even be slightly stronger because farmers may feel that their reduced use of potash over the past four years has left soil potassium content too low. But all such talk is purely speculative for now.

The other uses of potash, mainly to make potassium chemicals, show no upturn of any significance. And in any case, because they are so small, the nonfertilizer uses have a negligible effect on production.

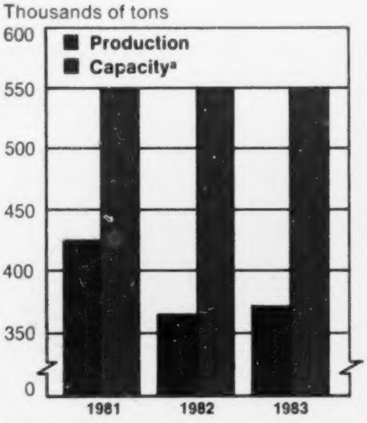
Key Chemicals

Phosphorus

P_4

- ***Demand depressed***
- ***Capacity may slip***
- ***Prices steady***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Reduction of phosphate rock in electric furnaces with carbon (coke) and silica as aids

MAJOR DERIVATIVES (U.S.)

Phosphoric acid and derivatives 85%

MAJOR END USES (U.S.)

Detergents 60%, foods and beverages 15%, metal treatment 10%, chemicals 10%

FOREIGN TRADE

Exports—down to about 10,000 tons in 1983, imports—negligible

PRICES

90 cents to $1.00 per lb at plants

COMMERCIAL VALUE

$700 million for production, 1983

This will not be a recovery year for phosphorus, which analysts predict will stay mired at about its 1982 recessionary pace. That's a disappointment for phosphorus producers, who had stabilized this product in the late 1970s after an earlier decline due to reformulations in its most important market, detergents. The way it now looks, U.S. phosphorus output this year will be about 40% below its all-time peak in 1970.

Phosphorus had a difficult first quarter this year and may show an output decline for the first half. Production has been held down to cut inventories in the face of weak demand. Even with a moderately strong second half, full-year production will do well to be up at all, perhaps 2%.

Estimates for 1983 phosphorus production range from 360,000 to 375,000 tons, quite close to 1982 production of about 365,000 tons. Even with a better than expected second half this year and a steady gain in 1984, production won't make it back to the 1981 level. And a new record above 1970 is out of the question.

Current capacity, including some shutdown, totals some 550,000 tons per year. In 1983, the operating rate will be 67% if production picks up a bit, roughly the same as in 1982. Capacity has held steady for a number of years, with no significant additions in more than a decade. Shutdowns and scrappages also have been minor. For the future, no real changes in capacity are expected other than possible scrapping of some small units now shut down.

Investment money for new phosphorus units hasn't materialized, in part because there is little room to raise prices of on-site derivatives, which take most phosphorus production. Another investment curb is that electric furnaces are very expensive, and producers and engineering companies don't have any recent experience in estimating costs of phosphorus plant projects. Then, too, possible competition from highly purified wet-process phosphoric acid in making many of the same derivatives is a potential threat to new elemental phosphorus investment.

This year, phosphorus plants in the Northwest might do well because the large snow melt this spring favors low-cost hydroelectric power. In contrast, Florida phosphorus plants are shut down because of higher power costs.

But even with favorable power costs for some phosphorus plants, demand has just begun to pick up in the general economic recovery. The first slug of the demand increase was met with inventories, completing a drawdown that began early in 1982. Renewed inventory building, if any, has been cautious.

Demand improvement in the detergent area will continue to follow the economy. This 60% segment of U.S. phosphorus use includes many applications, the largest being home laundry detergents; other applications include the many specialized industrial and commercial cleaners. Detergent demand has an apparent connection to industrial output; when industry picks up, people work more, and work clothes take a lot of detergent to clean. Detergent demand likely will be up enough in 1983 to cover both an export drop of as much as 5000 tons and some decline in making chemical derivatives.

Phosphorus-derived detergent phosphates are no longer plagued by regional phosphate bans in the U.S., which cut deeply into this market in the 1970s. However, continual reformulation in detergents can always drop phosphate levels.

About the only other significant use category expected to be up in 1983 will be food and beverages. Analysts forecast additional phosphoric acid demand in this market resulting from the introduction of more noncaffeine and other soft drinks, partly because of inventory needs.

Most other industrial and agricultural uses still will be down in 1983. For example, metal finishing applications such as aluminum polishing and phosphate coatings on steel are heavily dependent on the automobile industry, now recovering well on a unit-volume basis but not yet very strongly on a materials volume basis because of the earlier shift to smaller cars and light trucks. As with sulfur and potash, the government's payment-in-kind program could hold down sales of agricultural pesticides made from phosphorus intermediates. Most other uses of phosphorus and its derivatives are small, so even major changes would have only a minor effect on total demand.

JULY 18, 1983

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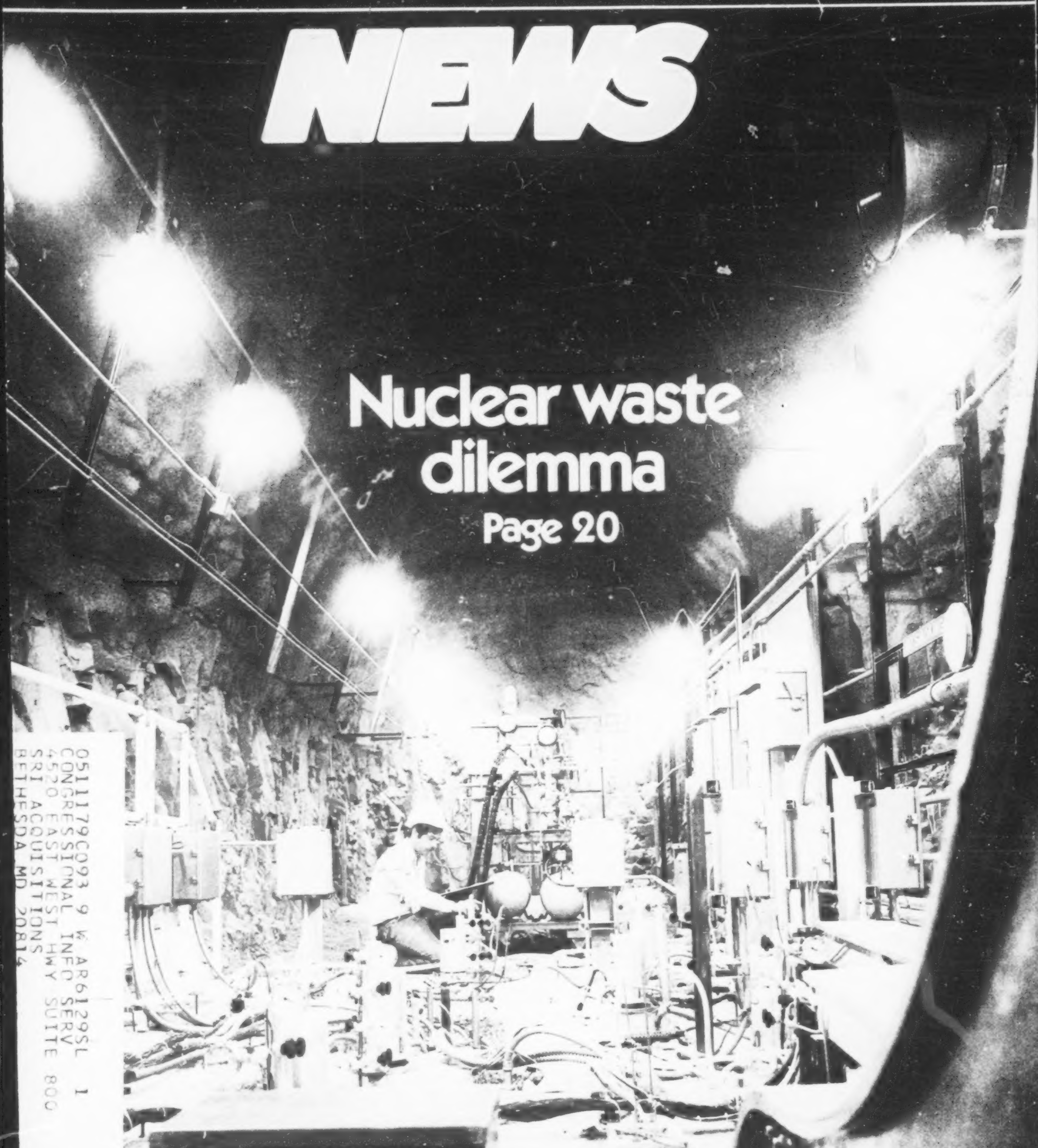
CHEMICAL & ENGINEERING NEWS



Nuclear waste dilemma

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Cover: Electric heaters simulate thermal effects of nuclear waste on basalt rock tunnel at Hanford, Wash. Photo by Battelle Photography

Volume 61, Number 29
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CHEMICAL & ENGINEERING
NEWS
JULY 18, 1983

News of the Week

- **Several pesticides could face suspension as a result of invalid testing done in the 1970s. Page 4**
- **Products that do not meet U.S. flammability standards now to be exported to other countries. Page 5**
- **Crackdown on dissident Soviet scientists of growing concern. Page 5**
- **Binary nerve gas weapon production gets tacit approval from Senate; amendment to delete funding for the weapons is defeated. Page 5**

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Technology

Underground coal gasification is to undergo crucial tests that could result in opening up more coal reserves; test auto built for DOE combines gas engine and electric motor. **Page 15**

Science

Searle Scholars Program awards $3 million worth of grants to research investigators. **Page 19**

Books

"The Puzzle Palace," by James Bamford, reveals the intrusive abilities of the National Security Agency. **Page 39**

NUCLEAR WASTE
DISPOSAL
?
DETOUR

Special Report

Finding sites for storing nuclear wastes has become a political time bomb; urgency generated by new waste law needs to be balanced by sagacity. Page 20

Key Tests Set for Underground Coal Gasification

National laboratory explores new methods that promise to open up more coal reserves, boost interest in coal-based synthetic fuels

Joseph Haggin, C&EN Chicago

Underground coal gasification (UCG) is about to undergo some crucial tests. Their successful conclusion would leave little doubt of the technique's technical feasibility and might even provide much needed economic impetus for some commercial ventures.

The tests, tentatively scheduled for late August, will be conducted by Lawrence Livermore National Laboratory (LLNL) near Centralia, Wash., in a coal seam owned by Washington Irrigation & Development Co. Three tests will check out a new UCG method being developed by LLNL.

Despite the on-again, off-again funding patterns in alternative (to oil and gas) fuel sources, UCG has managed to survive. Behind that survival is the dedication of a few believers and the irrefutable logic that it would be well to have a standby source of gas—both as competition to natural gas and as a well-developed technology—when natural gas reserves eventually become inadequate.

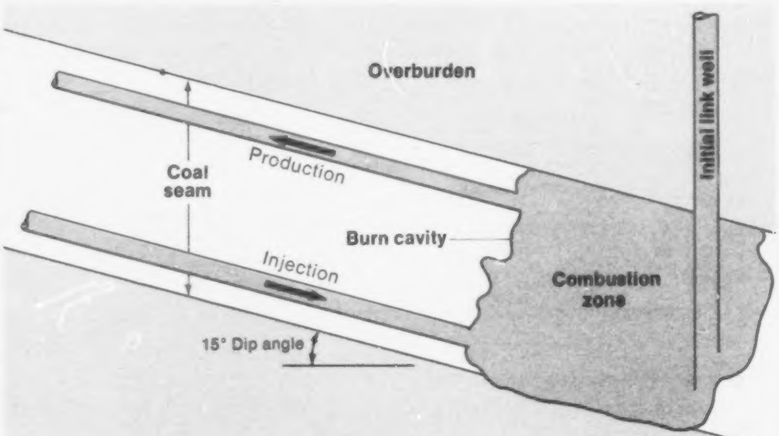
The declining appeal of coal mining, the inherent danger of mining, the escalating cost of extraction, and the somewhat limited reserves available to existing methods of mining have all held back any surge of interest in launching a new wave of coal extraction and conversion. There is no doubt that miners have been doing much to increase the yield of the mines each year. Billion-ton yearly totals have been reached, and that about fills present needs. The problem is that if alternatives to oil and gas are to be derived from coal, double, triple, and even greater multiples of present production probably would be required. Some observers doubt that this can be done without some dramatic changes in the way coal is mined and/or used. It is against this background that the building of a coal-based synthetic fuels industry is being carried out.

The U.S. development effort in UCG began in earnest in 1973 when the federal government began to fund tests. This came about the time of the Arab oil embargo.

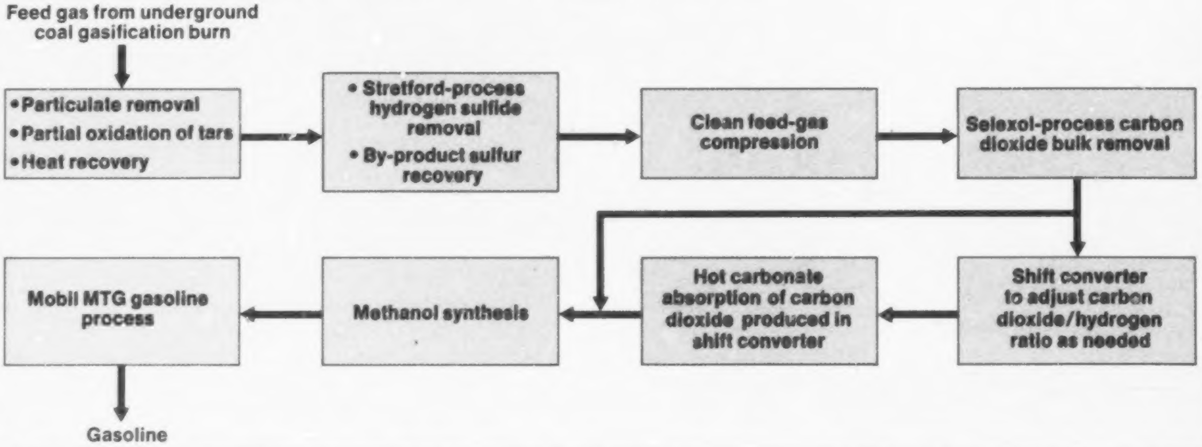
Since 1973, 20 successful UCG tests have been conducted in the U.S. Of these, 15 have been funded by the federal government, mostly in the western part of the country. Also, the Soviet Union has expended considerable effort over the years at gasifying coal underground. Despite questionable results in many of the Soviet trials, and some teething troubles in the U.S. effort, UCG has finally emerged as a candidate for synfuels production. This is the view of Douglas R. Stephens, who directs the LLNL program. He justifies this on the basis that the economics of UCG appear to be competitive, that a much greater fraction of absolute coal reserves can be made available with UCG, and that the environmental impact of UCG is small.

The UCG product is a synthesis gas, usually classified as a medium-Btu gas that can be used directly as a fuel gas or as a feedstock for substitute natural gas (SNG). With suitable adjustments in composition—the carbon monoxide-to-hydrogen ratio—the syngas also may be used as feedstock for other chemicals, most notably methanol and gasoline. Although the economics may be disputed on occasion, Stephens suggests that medium-Btu fuel gas can be made from UCG sources for about $4.35 per million Btu, and SNG for about $6.25 per million Btu. If the

Coal burn will use improved controlled retraction injection point (CRIP) method



Gasoline could be made via underground coal gasification


Feed gas from underground coal gasification burn
• Particulate removal
• Partial oxidation of tars
• Heat recovery
• Stretford-process hydrogen sulfide removal
• By-product sulfur recovery
Clean feed-gas compression
Selexol-process carbon dioxide bulk removal
Shift converter to adjust carbon dioxide/hydrogen ratio as needed
Hot carbonate absorption of carbon dioxide produced in shift converter
Methanol synthesis
Mobil MTG gasoline process
Gasoline

syngas from a UCG burn is used for a Mobil-MTG plant, the product gasoline may cost as little as $1.35 per gal. Excepting the price for gasoline, these are currently competitive prices in Stephens' view. In the case of methanol, current oversupply has depressed the price somewhat and this probably means that, in normal markets, UCG methanol would be easily competitive.

It has been estimated by various authorities that there are about 6 trillion tons of coal in the U.S. About 400 billion tons (6.7%) are available via conventional mining procedures. If UCG were employed, the amount of available coal could rise to about 1.8 trillion tons (30% of the total), says Stephens. Moreover, much of the coal in the increased total could not be mined by any other techniques, meaning that it would be unavailable under any other circumstances.

Aside from the inherent dangers in deep-seam mining, an overriding consideration in increasing coal use has been environmental impact. In the case of UCG, most of the usual environmental problems have been bypassed, but there are some problems. One of the most notable is occasional subsidence below ground and occasionally up to the surface. In such tests as the Hoe Creek series in Wyoming held from 1978 to 1980, subsidence has not been extensive, but neither have been the tests. On the basis of experience so far, prediction of subsidence isn't very reliable, but the effects also appear to be less than might have been suspected.

Another potential environmental problem is groundwater contamination by the UCG combustion and pyrolysis products and the abrupt changes in geology that result from removal of the coal. In particular, the possible linking of various aquifers might be detrimental if some of them are brackish or if the links change the hydrology of the strata in question. LLNL and other agencies have carried out some extensive tests before, during, and after a number of the UCG operational burns made to date. So far, there appear to be no real hazards, although all the data are not in.

The generation of potential pollutants in a UCG burn has been shown to occur. However, the natural adsorption properties of the overburden and underburden, in addition to the activated materials in the residual coal, tend to confine the possible pollutants to the immediate region of the burn.

At Hoe Creek and elsewhere, no great environmental impacts have been detected, but there are provisos. A very good geology survey is necessary before a burn, and extensive monitoring is required during and after the burn. This is usually enough to ensure minimal impact.

Traditionally, the technology of UCG has been rather low on the scale of sophistication, but that is changing. Through the efforts of the Department of Energy, LLNL, and such private operators as Gulf Oil, the Basic Resources division of Texas Utilities, and several foreign developers, the one great problem of controlling UCG burns and the many smaller problems gradually have become less perplexing.

Vertical wells, both for oxidant injection and product removal have been the historical standard, but are not always preferable. It is particularly difficult to maintain the integrity of a vertical injection well because of the threat of collapse of coal

Plant size affects cost of processing UCG gas to methanol

	4000 Bbl per day	12,000 Bbl per day	24,000 Bbl per day
Capital investment	$66.2 million	$130 million	$200 million
Raw gas cost, per 1000 standard cu ft	49 cents	42 cents	37 cents
Annual operating expenses	$29.2 million	$ 71 million	$123 million
By-product revenue, per year	$13 million	$ 39.1 million	$ 78.2 million
Methanol gate price, per bbl	$33.84	$ 25.56	$ 21.39

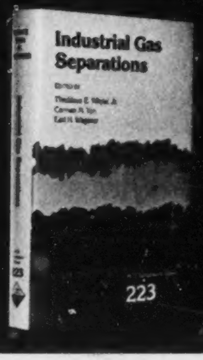
Note: 1981 dollars

and overburden. Failures of injection wells by plugging have been common. There has been less experience with horizontal injection wells, but they are considered to be more reliable. The principal cause of the troubles with injection wells has been the high temperatures in the pyrolysis zone. Production wells, by contrast, are easier to maintain because they can be cooled by steam and/or water injection to below the safe temperature of 500 °C.

The classic UCG burn is typically achieved by drilling two vertical holes into a seam that is either horizontal or slightly dipping. One hole serves for injection of air or oxygen to support combustion; the other conveys the pyrolysis/combustion products to the surface. As coal is consumed, the pyrolysis zone travels toward the injection well, and eventually the combustion either stops because the injection port is reached or because the well plugs. A classic operation includes a grid of wells, so drilled that the processes can be continued by repeatedly removing the injection wells along the grid as pyrolysis proceeds. In the case of a steeply dipping bed, the technique is more or less the same except that the injection and production wells become progressively shorter as pyrolysis continues.

A much-improved UCG system has been developed by Stephens and his associates at LLNL—the controlled retracting injection port (CRIP) method. In brief, the CRIP method requires two horizontal wells drilled along a coal seam. One is near the top of the seam and the other near the bottom. The bottom (injection) well is lined with metal pipe. The upper well is the production well. As pyrolysis proceeds, the burn cavity moves toward the base of the wells, progressively exposing more and more of the injection pipe. At an appropriate time, the pipe is melted or burned off and a new period of pyrolysis begins. In effect, the old problems of well plugging are circumvented by simply starting a new burn periodically along the horizontal wells. Experience so far has indicated that reliable gas flow control is afforded by CRIP, and the composition of the product gas is much more controllable.

Industrial Gas Separations



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Presents recent developments in membrane technology. Discusses emerging theories and applications of adsorption and absorption technologies relating to gas separation. Explores gas-transport mechanisms and models and presents several industrial applications of gas membranes. Includes discussion of a process for recovering methane from hydrogen and carbon monoxide using liquid propane. Also examines a process for removing acid gases (sulfur and carbon monoxide) where the contaminant carbon dioxide is both an active adsorbent and a component of an absorptive fluid.

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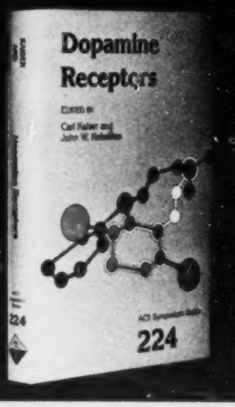
Dopamine Receptors



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National Institutes of Health

Analyzes and updates dopamine receptor research, including drug interaction, the "two dopamine receptor hypotheses," and novel agonists used as therapeutic agents. Allows reader to weigh evidence by presenting conflicting views at the end of most chapters.

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D-1 Dopamine Receptor-Mediated Activation of Adenylate Cyclase, cAMP Accumulation, and PTH Release in Dispersed Bovine Parathyroid Cells • D-2 Dopamine Receptor in Intermediate Lobe of Rat Pituitary Gland • Dopamine Receptor of Anterior Pituitary Gland • Differentiation of Dopamine Receptor in Periphery • Dopamine Receptors in Neostriatum • Potential Therapeutic Uses of Dopamine Receptor Agonists and Antagonists • Dopaminergic Benzazepines with Divergent Cardiovascular Profiles • Dopamine Agonists and Antagonists in Duodenal Ulcer Disease • Development of Novel Dopamine Agonists • Stereoisomeric Probes of Dopamine Receptor • Conformationally Defined Pyrroloisoquinoline Antipsychotics • Renal Vascular Dopamine Receptor Topography

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The CRIP method was first tried successfully in early 1982 with a three-day trial, gasifying a 40-ton cavity. The injection pipe was then burned off and a second 10-ton cavity started. The original cavity cooled to 500 °C, and the second achieved the typical operating temperature of 1000 °C. The average heating values of the product gases were between 265 and 277 Btu per standard cubic foot.

In addition to the improvements in UCG technology afforded by the CRIP method, LLNL also has overcome one of the other minor but always vexing problems: how to reliably start a burn. The usual approach in the past has been to use electrical resistance heating to achieve the high pyrolysis temperatures, or, sometimes, to use incendiary chemicals and explosives. The method now in use by LLNL involves pyrophoric silane and propane gases. The silane ignites upon encountering the oxygen in the burn cavity and burns long enough to subsequently ignite the propane, which is injected into the well. The propane actually ignites the coal in the cavity. At a suitable time, the propane is shut off and the pyrolysis sustains itself. This method has proved reliable since its adoption.

The CRIP method will be used in the projected tests in Washington over the next three years. Each of the three tests will be of longer duration and of greater scope, culminating with a very large, whole-seam test. These tests follow a recent series of large block tests in the same Big Dirty seam at the Washington Irrigation mine, and earlier laboratory tests conducted on small blocks of coal encased in drums. The general thrust of the entire series has been to assess the scale factors that apply to UCG operations and to aid in the mathematical modeling of the UCG process in general. After much trial and some error, reasonably good agreement has been achieved between theory and experimental results.

In general, when a burn begins, the product gas heating value, chemistry, and thermal efficiency all are excellent. Up to 280 Btu per scf have been achieved with oxygen injection, and thermal efficiencies as high as 90% have been obtained. When the burn reaches the overburden, the heat loss increases sharply and heating value and thermal efficiency drop correspondingly. The CRIP method permits retention of the initial values by effectively preventing the burn from ever reaching the overburden.

With the expectation of a controllable, reliable UCG burn, the obvious next step is to integrate the gasification into a larger system. Two such systems that have received first consideration are the manufacture of methanol and the further conversion of the methanol to gasoline via the Mobil MTG process.

Pritchard Corp., Kansas City, has done some conceptual process design and has further studied the feasibility of using the raw gas from a UCG burn as a feedstock for methanol synthesis and/or MTG gasoline. The criteria for the studies were provided by LLNL, and the study called for three different sized plants—4000, 12,000, and 24,000 barrels per day of methanol. The 12,000-bbl-per-day plant is considered the baseline design, and the assumption is that a typical western coal deposit would be involved, in particular Sweet Water County in Wyoming.

In the Pritchard design, raw gas from the UCG burn is first run through a particulates separator and then undergoes partial combustion with controlled amounts of oxygen to eliminate potential catalyst poisons and to remove tars by converting them to gas. There also is catalytic conversion of carbonyl sulfides, sulfur dioxide, and nitrogen oxides. The gas is then sent to a Stretford unit for hydrogen sulfide removal and subsequent generation of elemental sulfur. Following a two-stage compression, the clean gas is then sent to a Selexol unit for removal of the bulk carbon dioxide. A shift converter adjusts the carbon monoxide-hydrogen ratio to the appropriate value required by the methanol synthesis process, and any carbon dioxide formed in the shift reactor is removed by hot carbonate scrubbing. The purified gas then goes to the methanol synthesis unit. Several processes may be used depending on local economics. The raw methanol is purified by distillation and then sold.

The conceptual process devised by

Pritchard may be altered to substitute a Mobil MTG plant for the final methanol purification units. The net products are gasoline and a few other associated hydrocarbons. The byproducts of the process include elemental sulfur and carbon dioxide. The gasoline process would not be competitive unless at least the 24,000-bbl-per-day methanol plant could be used. For this size plant and larger ones, the economics of scale become considerable and even the gasoline is claimed to be competitive in price. ☐

Auto goes hybrid with gas-electric engine

A hybrid automobile, under development for some time by General Electric and others, has been completed. The one-of-a-kind test auto incorporates both an electric motor and a gasoline engine.

The hybrid car was designed to consume about 50% less gasoline than a conventional car of similar size over 11,000 miles of annual driving that consists of 10% city driving, with the balance on the open road. The two propulsion systems give the experimental vehicle the fuel savings of an electric one, since it runs entirely on batteries for most of the in-town driving. But it eliminates an electric vehicle's major drawback of limited range. With the gasoline engine, the hybrid can make long, even cross-country, trips without depleting its batteries.

Hybrid car, built for DOE, is designed to save gasoline through battery use

Michael Ciccarelli, GE's program manager for the hybrid vehicle project, calls the car a "technological insurance policy." It's aimed he says, at the day when the world's supply of petroleum runs low and gasoline prices rise sharply.

The hybrid car was built for the Department of Energy by a team of automotive and technology firms headed up by scientists and engineers at the GE Research & Development Center, Schenectady, N.Y. Among the major subcontractors, West Germany's Volkswagenwerk designed and built a specially modified, fast-starting 80-hp gasoline engine; Johnson Controls Inc., Milwaukee, supplied the 12-volt lead-acid batteries; and Triad Services Inc., Madison Heights, Mich., designed and fabricated the car's body and chassis, as well as constructed a full-size clay model used to make moldings from which particular body structures were cast. DOE's contract manager on the project was the Jet Propulsion Laboratory, Pasadena, Calif., to whom the car has been delivered for six months of extensive testing.

A key element in the car's operation is a microcomputer designed by GE that controls the entire hybrid system. The vehicle's 40-hp electric motor and 80-hp gasoline engine operate separately or in parallel, the electric motor employed primarily for speeds from zero to 40 miles per hour, and the gasoline engine for most highway driving. In situations in which both the electric motor and the gasoline engine are needed, such as in passing, the load is shared automatically. The microcomputer, reacting to the driver's "foot-pedal" commands, controls overall vehicle operation. It constantly monitors the battery pack's state-of-charge and other parameters and decides when to switch on the electric motor, the gasoline engine, or both.

The car's electric motor is powered by 10 batteries that weigh a total of 750 lb. The battery pack may be recharged by the gasoline engine when it is in operation or by wall-plug electricity using a specially designed on-board battery charger. The car also is equipped with a regenerative braking system that feeds recharge energy to the batteries when the brakes are applied. ☐

Nineteen get Searle scholar grants in 1983

Since the beginning of the Searle Scholars Program in 1980, 47 research investigators have received grants totaling about $4 million for biomedical research. Nineteen more recipients have been named for 1983, each receiving $157,000 for the next three years. The $3 million in grants awarded in 1983 raises to about $7 million the total funds distributed.

The Searle Scholars Program, which has more than $50 million in monies available, was initiated under terms of the will of the late John G. Searle, former president of G. D. Searle & Co., the Skokie, Ill., pharmaceutical firm. Searle established several trusts, the income from which he directed to be used for research in medicine, chemistry, and the biological sciences. Searle's widow left additional funds in trust for the program. The trustees of Searle's will agreed that the best way to use the funds would be through research grants to newly established investigators, primarily in academic laboratories. The intention is to encourage younger investigators who show promise in their chosen fields of research.

Applicants for grants from the Searle Scholars Program have their proposals screened by an advisory committee, currently chaired by David Shemin, professor of biochemistry and molecular biology at Northwestern University. The recommendations of the advisory committee are then passed to the administrators of the program for action. Recommendations are made on the basis of the prospective recipient's being a scientist of recognized ability, who is likely to continue to make important research contributions in his or her chosen field. Grants are used with considerable flexibility, the major criterion being the best scientific judgment of the recipient.

The Searle Scholars Program is under the administrative control of the Chicago Community Trust, a community foundation established in 1915. Cedric L. Chernick, formerly vice president for sponsored programs at the University of Chicago, is director of the program. ☐

JULY 25, 1983

CHEMICAL & ENGINEERING

NEWS

Facts & Figures for

Chemical R&D

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Cover: Deborah Haitko, chemist at GE's R&D center, Schenectady, N.Y., works on polyphenylene oxide polymerization process.

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CHEMICAL & ENGINEERING NEWS

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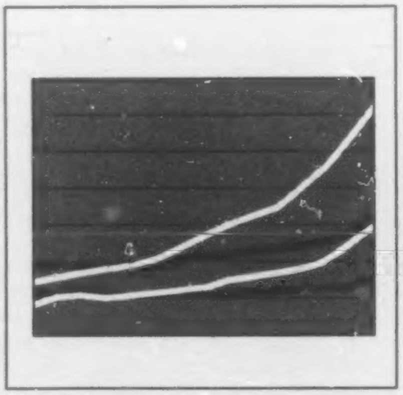
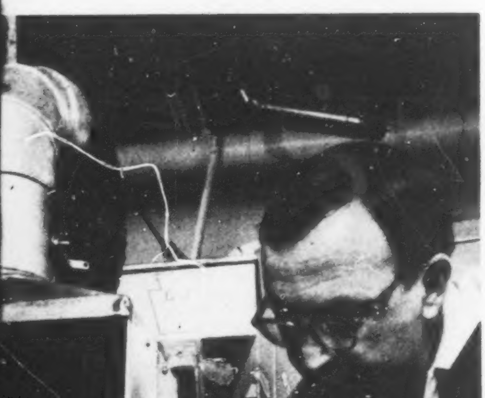


Special Report

Outpacing inflation, chemical R&D expenditures in the U.S. continue a steady upward trend, notably in industry. **Page 20**

Facts & Figures for Chemical R&D



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U.S. spending for research and development continues its upward trend, increasing 9% this year to $86.5 billion, according to estimates of the National Science Foundation. Even when inflation is taken into account, R&D spending actually will grow an estimated 4%. That's better than last year's 3% growth in constant dollars, although it falls short of the 5%-a-year increase, in real terms, between 1978 and 1981. The poorest year for R&D of the past decade was 1975, when spending in constant dollars declined 2%.

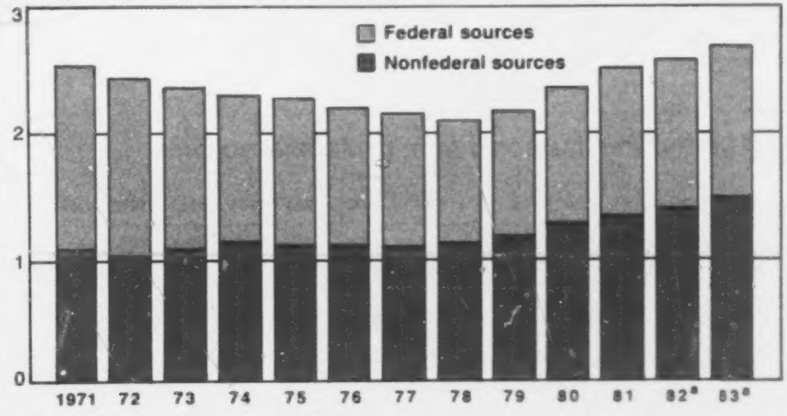
The best gain this year is expected on the development end of the overall R&D budget, which accounts for 65% of the total and is estimated to rise 5%, after adjustment for inflation. Basic and applied research are both slated for increases of only 3%.

The composition and character of this spending is depicted by the data reported on the following pages of C&EN's fifth annual survey of R&D spending and manpower in the U.S., with emphasis on chemistry and chemical engineering. Information is presented on where R&D funds come from, what types of R&D are being carried out, and who does the work.

One way to gauge the level of a nation's expenditures for R&D is to look at it as a percentage of gross national product. The percentage in the U.S. is expected to rise to nearly 2.7% in 1983, up from 2.6% last year. In

R&D's share of GNP is highest in more than a decade

R&D spending as % of U.S. gross national product



a Estimated. **Source:** National Science Foundation

1964, spending for R&D reached a high of 3.0% of GNP, then gradually decreased to 2.2% in 1978. Since then, however, it has risen every year.

The increase largely has reflected the relative growth in funds from sources outside the federal government, more than 90% of which are accounted for by private industry. Funds from nonfederal sources will edge above 1.4% of GNP this year, according to NSF, up from 1.1% five years ago and just under that level 10 years ago. On the other hand, funds from federal sources will be 1.2% of GNP this year, up from 1.1% in 1978 but slightly below the level in 1973.

Federal support of R&D is likely to rise 8% this year, which works out to a gain of just 3% in real terms. And nearly all that gain stems from the increased focus on defense spending. The defense-related segment of the federal R&D budget has climbed from 47% of the total in 1980 to 59% of the total this year, whereas civilian-related work (excluding space R&D) has dropped from 38% to 26% of the total. One agency that has seen its R&D funding shrink markedly in recent years is the Department of Energy, which the Administration has talked of abolishing.

Meanwhile, industry is increasing its spending 11%—5% after adjustment for inflation—in 1983, exclusive of federally supplied R&D funds. During the past five years, industry funding of R&D has climbed at an average annual rate of more than 6% a year, in constant dollars, but government support has risen less than 3% a year.

In U.S. universities and colleges, on the other hand, where most basic research is undertaken, growth essentially has stagnated. Spending this year, including money from industry and government, will be up a mere 1%, in real dollars, and will be less than it was two years ago. ☐

SECTION 1 R&D

Overview

A gain of 7% seen in real spending for R&D next year

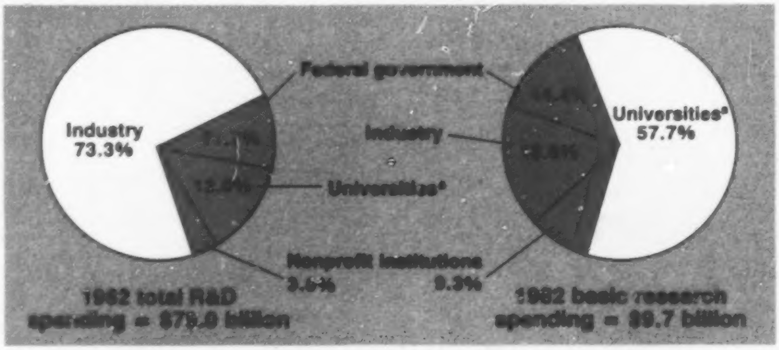
Easing of inflation means budget increases go further, as industry sets the pace in R&D funding while growth lags at universities and other nonprofit organizations

Total spending for research and development in the U.S. is expected to climb to about $97.0 billion next year, a gain of 12% over 1983, according to estimates by the National Science Foundation. When inflation is taken into account, the increase is 7%. It's been nearly 20 years since real growth in R&D has been so great. Slowing inflation is largely responsible, to be sure.

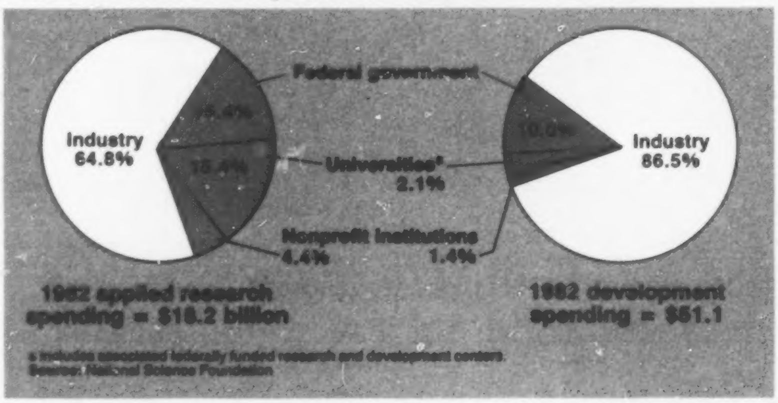
Since 1980, the chief U.S. source of R&D funds has been industrial firms; previously, the federal government was the main supplier. Universities and other nonprofit institutions are relatively minor sources. Industry's share of total R&D funding grew from 43% in 1973 to 49% in 1980 and is expected to be 51% in 1984. In the mid-1960s, nonfederal organizations of all types furnished only 35% of total R&D funds. Currently, they supply 54% and are expected to account for an even greater percentage in the years ahead.

Industry, too, is by far the major performer of R&D. In 1984, it is expected to spend $73.3 billion, 76% of total R&D outlays and a 14% increase from the previous year. Nearly a third of these outlays are funds from the federal government, but the share of industrial R&D that has federal funding has been shrinking.

Although academia does most basic research, private industry carries out the most R&D overall . . .



. . . because of industrial labs' big share of applied research and development work



a Includes associated federally funded research and development centers. **Source:** National Science Foundation

TRENDS IN R&D: Since 1979, most R&D funding has come from nonfederal sources

% of total outlays	1983^a	1982^a	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964
Federal	46%	46%	47%	47%	49%	50%	51%	51%	51%	51%	53%	56%	56%	57%	58%	61%	62%	64%	65%	66%
Defense related	27	25	24	22	23	24	26	26	26	27	30	32	32	33	34	35	35	33	33	37
Space related	7	7	7	7	7	7	7	8	8	8	8	8	9	10	11	13	14	19	21	19
Civilian related	12	14	16	18	19	19	18	17	17	16	15	16	15	14	13	13	13	12	11	11
Nonfederal	54	54	53	53	51	50	49	49	49	49	47	44	44	43	42	39	38	36	35	34

a Estimated. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: Funding by industry shows marked increase in recent years . . .

$ Billions, current	1984[a]	1983[a]	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Federal government	$44.5	$39.6	$36.6	$33.8	$29.7	$26.9	$23.9	$21.6	$19.9	$18.1	$16.9	$16.4	8%	9%
Industry	49.8	44.3	40.0	35.9	30.8	26.1	22.5	19.6	17.7	15.8	14.9	13.3	11	13
Universities and colleges	1.7	1.6	1.5	1.5	1.3	1.2	1.0	0.9	0.8	0.7	0.7	0.6	5	10
Other nonprofit institutions	1.0	1.0	0.9	1.0	0.9	0.8	0.8	0.7	0.6	0.5	0.5	0.4	9	10
TOTAL	**$97.0**	**$86.5**	**$79.0**	**$72.1**	**$62.7**	**$55.0**	**$48.2**	**$42.8**	**$39.0**	**$35.2**	**$32.9**	**$30.7**	9%	11%

a Estimated. **Source:** National Science Foundation

. . . but support by universities and other nonprofits changed little in constant dollars

$ Billions, constant (1972)	1984[a]	1983[a]	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Federal government	$19.5	$18.1	$17.6	$17.3	$16.7	$16.4	$15.9	$15.4	$15.1	$14.5	$14.8	$15.6	3%	2%
Industry	21.8	20.3	19.3	18.4	17.2	16.0	14.9	14.0	13.4	12.6	12.9	12.6	5	5
Universities and colleges	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0	2
Other nonprofit institutions	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	3	0
TOTAL	**$42.4**	**$39.6**	**$38.0**	**$36.9**	**$35.2**	**$33.6**	**$32.0**	**$30.5**	**$29.5**	**$28.2**	**$28.8**	**$29.2**	4%	3%

a Estimated. **Source:** National Science Foundation

PERFORMERS OF R&D: Industry pushes its share of total up to 76% . . .

$ Billions, current	1984[a]	1983[a]	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Industry	$73.3	$64.3	$57.9	$51.8	$44.5	$38.2	$33.3	$29.8	$27.0	$24.2	$22.9	$21.2	11%	12%
Federal government	10.5	9.8	9.3	8.7	7.8	7.5	6.9	6.1	5.8	5.4	4.9	4.8	5	7
Universities and colleges	7.8	7.4	7.0	6.8	6.1	5.4	4.6	4.1	3.7	3.4	3.0	2.9	6	10
Associated FFRDCs[b]	2.7	2.6	2.5	2.5	2.2	1.9	1.7	1.4	1.1	1.0	0.9	0.8	2	13
Other nonprofit institutions	2.7	2.5	2.4	2.3	2.2	2.0	1.7	1.5	1.4	1.3	1.2	1.0	6	10
TOTAL	**$97.0**	**$86.5**	**$79.0**	**$72.1**	**$62.7**	**$55.0**	**$48.2**	**$42.8**	**$39.0**	**$35.2**	**$32.9**	**$30.7**	9%	11%

a Estimated. b Federally funded research and development centers administered by universities and colleges. **Source:** National Science Foundation

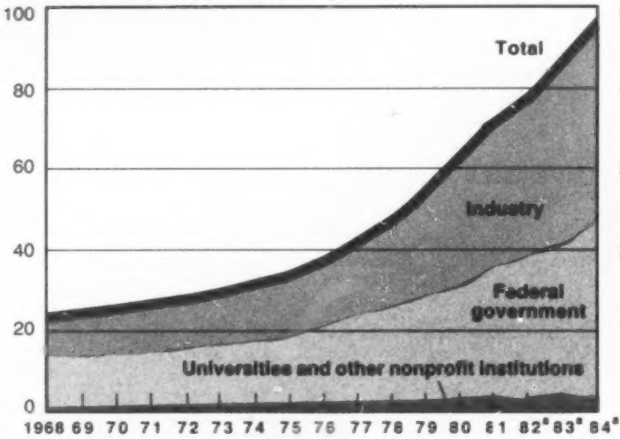
. . . as it makes the only noticeable gain recently after adjustment for inflation

$ Billions, constant (1972)	1984[a]	1983[a]	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Industry	$32.0	$29.5	$27.9	$26.5	$24.9	$23.4	$22.1	$21.3	$20.4	$19.2	$19.9	$20.1	6%	4%
Federal government	4.6	4.4	4.4	4.5	4.4	4.6	4.6	4.3	4.4	4.3	4.4	4.6	0	−1
Universities and colleges	3.4	3.4	3.4	3.5	3.4	3.3	3.1	[illegible]	2.8	2.8	2.7	2.8	1	2
Associated FFRDCs[b]	1.2	1.2	1.2	1.3	1.3	1.2	1.1	1.0	0.9	0.8	0.8	0.8	−3	4
Other nonprofit institutions	1.2	1.1	1.1	1.2	1.2	1.2	1.1	1.1	1.0	1.0	1.0	1.0	1	1
TOTAL	**$42.4**	**$39.6**	**$38.0**	**$36.9**	**$35.2**	**$33.6**	**$32.0**	**$30.5**	**$29.5**	**$28.2**	**$28.8**	**$29.1**	4%	3%

a Estimated. b Federally funded research and development centers administered by universities and colleges. **Source:** National Science Foundation

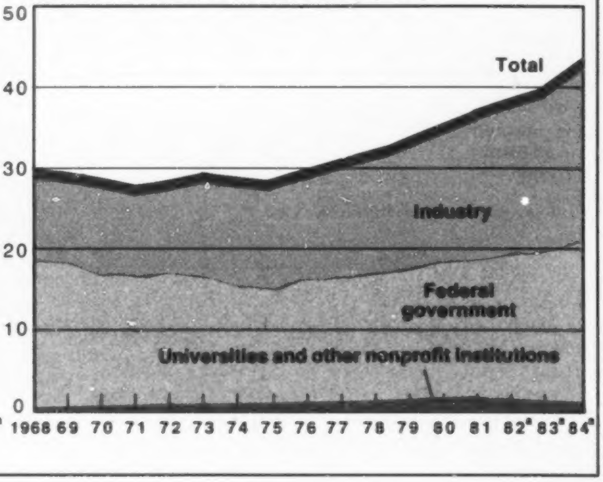
Spending for R&D has continued to climb during past 15 years . . .

Sources of R&D funds, $ billions, current



. . . with increases since 1975 having more than matched inflation

Sources of R&D funds, $ billions, constant (1972)



a Estimated. **Source:** National Science Foundation

CHARACTER OF R&D: Spending on development will rise most in 1983 . . .

$ Billions, current	1983ª	1982ª	1981ª	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Basic research	$10.5	$ 9.7	$ 9.2	$ 8.1	$ 7.3	$ 6.4	$ 5.5	$ 5.0	$ 4.6	$ 4.2	$ 3.9	8%	5%
Applied research	19.7	18.2	16.9	14.1	12.4	10.8	9.7	9.0	7.9	7.2	6.6	8	12
Development	56.3	51.1	46.1	40.6	35.4	31.0	27.5	25.0	22.7	21.4	20.2	10	11

a Estimated. **Source:** National Science Foundation

. . . but inflation offsets half the gain

$ Billions, constant (1972)	1983ª	1982ª	1981ª	1980	1979	1978	1977	1976	1975	1974	1973	Annual change 1982–83	Annual change 1973–83
Basic research	$ 4.8	$ 4.7	$ 4.7	$ 4.5	$ 4.4	$ 4.2	$ 3.9	$ 3.8	$ 3.7	$ 3.8	$ 3.8	3%	2%
Applied research	9.0	8.8	8.6	7.9	7.6	7.2	6.9	6.8	6.3	6.3	6.3	3	4
Development	25.8	24.6	23.6	22.7	21.6	20.6	19.7	18.9	18.1	18.7	19.1	5	3

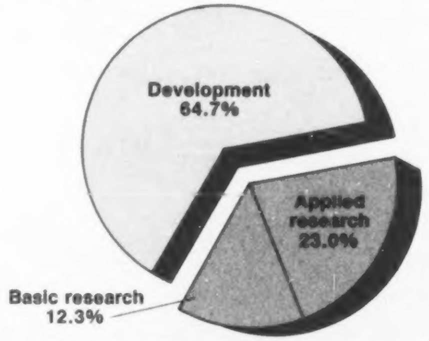
a Estimated. **Source:** National Science Foundation

EMPLOYED SCIENTISTS AND ENGINEERS: Chemists account for 9% of all scientists

Thousands	1981ª	1980	1978	1976	1974
Physical scientists	**229.5**	**223.2**	**212.4**	**227.4**	**201.4**
Chemists	147.6	143.3	143.7	150.4	133.5
Physicists/ astronomers	60.0	59.9	51.2	58.6	52.7
Engineers	**1479.4**	**1412.1**	**1268.4**	**1240.7**	**1212.6**
Chemical	79.4	73.4	62.0	na	na
Other scientists	**1425.2**	**1275.2**	**992.4**	**909.1**	**834.2**
TOTAL	**3134.1**	**2910.5**	**2473.2**	**2377.2**	**2248.2**

a Estimated. na = not available. **Source:** National Science Foundation

Development work takes nearly two thirds of total R&D spending



1982 total R&D spending = $79.0 billion

Source: National Science Foundation

ABSTRACTS OF PAPERS IN CHEMICAL ABSTRACTS: Most active area is biochemistry

% IN EACH GROUP	1982	1981	1980	1979	1978	1977	1976	1975	1974
Biochemistry	39.5%	39.0%	39.8%	38.8%	38.3%	37.9%	38.8%	39.4%	36.2%
Physical, inorganic, and analytical chemistry	28.5	28.0	28.6	28.9	27.4	27.9	27.5	29.6	29.7
Applied chemistry and chemical engineering	19.5	19.1	18.9	19.4	20.8	19.7	18.8	15.5	18.4
Organic chemistry	7.2	8.7	7.4	7.6	8.0	8.8	8.7	9.0	9.4
Macromolecular chemistry	5.3	5.2	5.3	5.3	5.5	5.7	6.2	6.5	6.3
% OF ALL BIOCHEMISTRY ABSTRACTS									
Mammalian biochemistry[a]	11.6%	15.6%	16.3%	17.1%	17.2%	17.7%	16.3%	15.3%	16.6%
Pharmacology	12.0	12.4	12.0	11.9	12.3	12.0	12.0	12.0	11.1
Toxicology	8.1	8.7	8.3	7.4	7.5	6.2	6.4	6.6	5.6
General biochemistry	6.0	7.5	6.6	7.0	6.5	7.0	7.1	7.5	7.3
Enzymes	5.9	5.9	6.2	6.4	5.7	6.1	6.4	7.4	6.4
Others	56.4	49.9	50.6	50.2	50.8	51.0	51.8	51.2	53.0
% OF ALL PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY ABSTRACTS									
Nuclear chemistry	22.6%	21.6%	23.2%	25.1%	20.7%	21.1%	19.7%	20.0%	15.8%
Spectra	17.2	18.0	18.2	17.0	17.0	18.1	17.8	17.2	18.2
Electric phenomena	10.5	11.0	11.2	11.4	10.9	10.5	10.5	10.3	11.4
Crystallography and liquid crystals	8.7	8.9	8.1	8.2	9.2	8.9	9.7	9.6	10.1
General physical chemistry	7.3	7.2	7.1	6.6	6.6	6.8	7.0	6.8	6.4
Analytical chemistry	5.4	5.8	5.6	5.6	7.2	5.8	6.6	6.1	7.4
Others	28.3	27.5	26.6	25.8	28.4	28.8	28.7	30.0	30.7
% OF ALL APPLIED CHEMISTRY AND CHEMICAL ENGINEERING ABSTRACTS									
Metals and alloys	22.2%	17.9%	22.0%	23.6%	24.0%	24.2%	27.8%	24.4%	27.9%
Water, wastes, and pollution	21.7	24.0	22.5	20.8	20.8	23.2	18.6	15.2	18.2
Mineralogical and geological chemistry	13.6	14.1	15.7	15.8	16.8	13.4	17.6	17.5	17.6
Fossil fuels, derivatives, and related products	9.4	9.4	8.9	7.8	8.2	9.2	6.0	9.8	4.0
Unit operations and processes	6.9	6.4	6.0	6.1	6.4	5.8	4.8	5.3	5.6
Others	26.2	28.2	24.9	25.9	23.8	24.2	25.2	27.8	26.7
% OF ALL ORGANIC CHEMISTRY ABSTRACTS									
Physical organic chemistry	31.5%	37.0%	38.6%	38.8%	36.8%	41.3%	38.4%	40.8%	37.3%
Heterocyclic compounds[a]	15.6	18.2	17.3	16.0	17.5	17.0	17.4	16.4	17.3
Organometallic and organometalloidal compounds[a]	14.8	8.3	8.2	8.5	8.9	8.5	8.7	8.4	8.2
Aromatic compounds[a]	7.2	8.7	7.8	8.2	8.6	8.5	8.0	8.7	9.4
Aliphatic compounds[a]	5.2	6.6	6.0	6.0	6.9	5.9	6.5	6.3	7.1
Carbohydrates	5.8	5.4	5.7	6.0	5.2	4.6	5.1	4.9	5.5
Others	19.9	15.8	16.2	16.5	16.1	14.2	15.9	14.5	15.2
% OF ALL MACROMOLECULAR CHEMISTRY ABSTRACTS									
Synthetic high polymers	34.7%	30.3%	27.0%	26.3%	25.6%	26.5%	28.3%	30.6$	30.6%
Plastics manufacture and uses	21.9	26.4	28.1	27.8	28.1	27.5	26.8	23.3	23.1
Cellulose, lignin, paper, and other wood products	9.7	10.1	10.9	11.1	10.6	10.0	9.1	9.2	9.2
Textiles	8.9	9.9	10.1	10.1	12.1	11.0	11.1	10.2	9.8
Coatings, inks, and related products	7.6	7.5	7.4	8.1	7.5	7.5	7.6	7.3	8.1
Synthetic elastomers and natural rubber	7.8	7.9	8.4	7.6	8.0	8.5	8.6	9.2	10.4
Others	9.4	7.9	8.1	9.0	8.1	9.0	8.5	10.2	8.8

a Definition of section content changed in 1982. Source: Chemical Abstracts Service

U.S. PATENTS: Number granted to U.S. residents dropped more than those to foreigners in 1982

	1982	1981	1980	1979[a]	1978	1977	1976	1975	1974	1973	1972
U.S.[b]	33,896	37,356	37,152	30,605	40,979	41,383	44,162	46,603	50,643	51,501	51,515
Foreign[c]	23,993	24,463	24,675	18,248	25,123	23,886	26,074	25,291	25,632	22,638	23,293
TOTAL	**57,889**	**61,819**	**61,827**	**48,853**	**66,102**	**65,269**	**70,236**	**71,994**	**76,275**	**74,139**	**74,808**
% Foreign	**41.4%**	**39.6%**	**39.9%**	**37.4%**	**38.0%**	**36.6%**	**37.1%**	**35.3%**	**33.6%**	**30.5%**	**31.1%**

a Patent figures were low in 1979 because the Patent & Trademark Office was short of funds to print patents it might otherwise have issued. b U.S. patents granted to U.S. residents. c U.S. patents granted to residents of foreign countries. Source: Patent & Trademark Office

Military work accounts for most federal R&D growth

Chemical research is getting less federal support in fiscal 1983, reflecting cutbacks for energy and environmental work

FEDERAL OBLIGATIONS FOR R&D: Defense and space account for nearly three quarters

Department or agency	Total R&D ($ millions)				
	1983[a]	1982[a]	1981	1980	1979
Agriculture	**$ 838.9**	**$ 807.4**	**$ 774.0**	**$ 687.6**	**$ 663.0**
Agricultural Research Service	454.5	412.0	394.1	351.8[b]	345.8[b]
Cooperative State Research Service	223.3	221.2	199.4	184.2[c]	172.6[c]
Commerce	**234.7**	**280.9**	**328.0**	**342.5**	**309.4**
National Bureau of Standards	80.3	90.3	82.5	76.2	67.8
Defense	**24,519.6**	**20,602.3**	**16,508.6**	**13,981.0**	**12,506.2**
Air Force	11,405.0	9,355.8	6,969.2	5,211.0	4,525.6
Army	4,594.3	3,702.2	3,244,2	2,980.0	2,768.7
Navy	6,251.4	5,820.2	5,006.0	4706.1	4,335.0
Energy	**3,944.2**	**4,583.5**	**4,918.2**	**4,753.7**	**4,638.8**
Environmental Protection Agency	**229.9**	**317.1**	**235.7**	**345.0**	**410.1**
Health & Human Services	**4,117.8**	**3,967.9**	**3,927.1**	**3,780.2**	**3,504.9**
National Institutes of Health	3,534.6	3,428.7	3,333.2	3,181.8	2,953.1
Interior	**364.7**	**403.4**	**427.1**	**411.3**	**405.8**
National Aeronautics & Space Administration	**6,512.9**	**5,841.3**	**5,406.6**	**5,084.1**	**4,411.0**
National Science Foundation	**1,025.1**	**959.6**	**961.6**	**881.8**	**807.9**
Tennessee Valley Authority	**74.2**	**81.7**	**68.9**	**80.1**	**38.4**
Others	**1,111.8**	**1,109.0**	**1,271.6**	**1333.1**	**1,282.2**
TOTAL	**$42,973.8**	**$38,954.1**	**$34,917.4**	**$31,680.4**	**$28,977.7**

a Estimated. b Agricultural R&D in Science & Education Administration. c Cooperative R&D in Science & Education Administration. Note: Fiscal years. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR RESEARCH: Biggest share is for health and defense

Department or agency, $ millions	1983[a]		1982[a]		1981		1980		1979	
	Basic research	Applied research	Basic research	Applied research	Basic research	Applied research	Basic research	Applied research	Basic research	Applied research
Agriculture	**$ 359.1**	**$ 449.1**	**$ 332.1**	**$ 443.3**	**$ 314.1**	**$ 426.9**	**$ 275.7**	**$ 381.8**	**$ 256.4**	**$ 375.5**
Agricultural Research Service	221.6	206.7	196.1	189.6	186.4	181.5	157.8[b]	170.8[b]	148.2[b]	172.7[b]
Cooperative State Research Service	96.4	126.9	91.9	129.3	83.9	115.5	75.2[c]	109.0[c]	70.5[c]	102.1[c]
Commerce	**17.8**	**168.3**	**17.5**	**202.4**	**16.2**	**233.2**	**15.9**	**238.5**	**11.9**	**207.6**
National Bureau of Standards	17.3	54.7	16.9	55.0	15.6	50.6	12.8	46.1	8.8	43.0
Defense	**782.1**	**2543.9**	**674.2**	**2208.9**	**604.3**	**1996.6**	**540.3**	**1721.4**	**471.5**	**1542.6**
Air Force	164.2	542.0	140.4	452.0	125.8	491.5	108.2	429.1	105.0	387.2
Army	203.6	505.0	167.1	416.4	148.1	388.4	132.2	347.1	115.0	333.6
Navy	305.0	546.3	280.0	490.6	238.0	460.0	214.9	396.2	192.1	375.2
Energy	**738.7**	**760.4**	**646.8**	**895.5**	**586.3**	**827.3**	**523.1**	**754.2**	**463.0**	**668.9**
Environmental Protection Agency	**9.8**	**150.0**	**14.7**	**201.9**	**10.5**	**207.8**	**13.6**	**231.5**	**10.1**	**248.9**
Health & Human Services	**2042.3**	**1660.9**	**1970.7**	**1583.5**	**1900.4**	**1591.9**	**1762.7**	**1570.1**	**1576.0**	**1439.7**
National Institutes of Health	1896.7	1249.6	1839.4	1207.7	1766.8	1181.5	1642.3	1145.1	1463.7	1066.4
Interior	**67.6**	**251.0**	**74.2**	**275.7**	**80.7**	**289.2**	**71.6**	**282.8**	**72.5**	**266.9**
National Aeronautics & Space Administration	**677.2**	**854.5**	**575.3**	**809.5**	**531.1**	**876.0**	**559.1**	**1050.5**	**512.8**	**938.4**
National Science Foundation	**975.6**	**49.6**	**910.8**	**48.8**	**896.6**	**58.9**	**815.2**	**58.4**	**733.3**	**66.8**
Tennessee Valley Authority	**5.7**	**17.7**	**5.2**	**13.9**	**4.8**	**9.4**	**4.6**	**11.2**	**4.1**	**12.4**
Others	**89.3**	**594.3**	**89.3**	**600.7**	**96.3**	**654.3**	**92.4**	**622.8**	**81.1**	**574.6**
TOTAL	**$5765.2**	**$7499.7**	**$5310.8**	**$7284.1**	**$5041.3**	**$7171.5**	**$4674.2**	**$6923.2**	**$4192.7**	**$6342.3**

a Estimated. b Agricultural R&D in Science & Education Administration. c Cooperative R&D in Science & Education Administration. Note: Fiscal years. Source: National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Support for chemistry slips in 1983

$ Millions for research only	1983[a]	1982[a]	1981	1980	1979	Annual change 1982–83	Annual change 1979–83
Engineering	$ 3,172	$ 3,137	$ 3,072	$ 2,830	$ 2,572	1%	5%
Chemical	144	150	148	96	114	−4	4
Metallurgy and materials	314	294	256	236	249	7	6
Environmental sciences	1,098	1,093	1,121	1,261	1,101	0	−1
Life sciences	4,735	4,593	4,436	4,192	3,848	3	5
Mathematics and computer sciences	357	311	279	241	210	15	9
Physical sciences	2,846	2,510	2,221	2,001	1,793	13	12
Chemistry	533	645	487	455	444	−17	4
Physics	1,762	1,396	1,346	1,183	1,023	26	14
Other sciences	1,057	952	1,085	1,072	1,011	11	1
TOTAL	$13,265	$12,595	$12,213	$11,597	$10,535	5%	6%

a Estimated. **Note:** Fiscal years. **Source:** National Science Foundation

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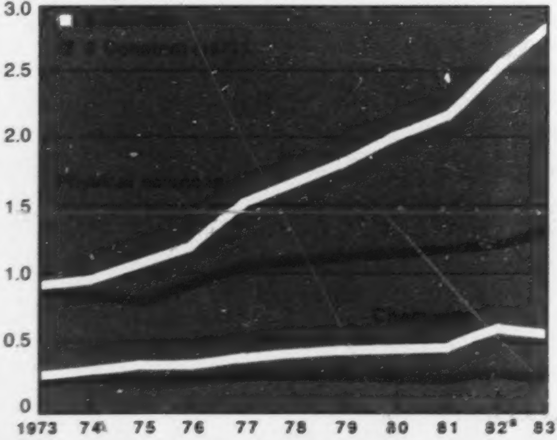
FEDERAL OBLIGATIONS FOR DEVELOPMENT: About 70% goes for defense

Department or agency	Development ($ millions) 1983[a]	1982[a]	1981	1980	1979
Agriculture	$ 30.7	$ 32.0	$ 33.0	$ 30.2	$ 31.1
Agricultural Research Service	26.2	26.2	26.2	23.3[b]	24.9[b]
Cooperative State Research Service	0	0	0	0[c]	0[c]
Commerce	48.6	61.0	78.6	88.1	89.9
National Bureau of Standards	8.2	18.5	16.3	17.3	16.0
Defense	21,193.6	17,719.1	1[illegible],907.7	11,719.[illegible]	10,492.1
Air Force	10,698.8	8,783.4	6,351.9	4,673.7	4,033.4
Army	3,885.7	3,118.7	2,707.7	2,500.7	2,320.1
Navy	5,400.1	5,049.6	4,308.0	4,095.0	3,767.7
Energy	2,445.1	3,041.2	3,504.6	3,476.4	3,506.9
Health & Human Services	414.5	413.8	434.9	447.4	489.2
National Institutes of Health	388.3	381.6	384.9	394.4	423.0
Interior	46.0	53.6	57.3	56.8	66.3
Environmental Protection Agency	70.1	100.5	107.4	99.9	151.1
National Aeronautics & Space Administration	4,981.2	4,456.5	3,999.4	3,474.4	2,959.8
National Science Foundation	0	0	6.1	8.1	7.9
Tennessee Valley Authority	50.8	62.6	54.7	64.3	21.9
Others	428.3	418.8	520.9	618.2	626.5
TOTAL	$29,708.9	$26,359.1	$22,704.6	$20,083.0	$18,442.7

a Estimated. b Agricultural R&D in Science & Education Administration. c Cooperative R&D in Science & Education Administration. **Note:** Fiscal years. **Source:** National Science Foundation

Chemistry accounts for a fifth of federal funding for physical science research

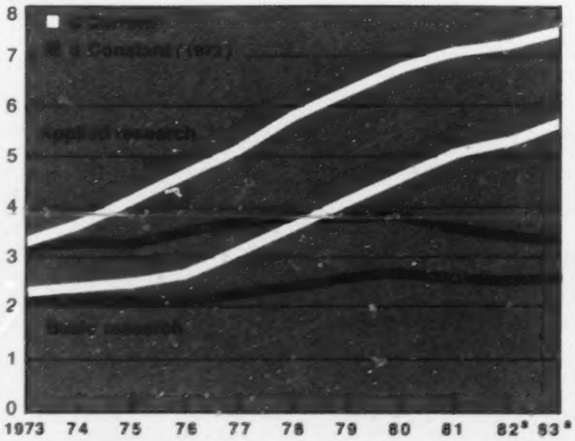
Federal obligations for research, $ billions



a Estimated. **Note:** Fiscal years. **Source.** National Science Foundation

Government support of research, in real terms, little changed in recent years

$ Billions



a Estimated. **Note:** Fiscal years **Source:**National Science Foundation

BASIC RESEARCH: NSF and Energy Department remain major backers for chemistry

	Federal obligations ($ millions)									
	1983[a]		1982[a]		1981		1980		1979	
Department or agency	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Agriculture	$ 40.5	$ 38.7	$ 36.9	$ 35.1	$ 33.7	$ 31.8	$ 25.8	$ 24.0	$ 23.8	$ 22.3
Agricultural Research Service	34.4	33.2	30.5	29.4	27.7	26.5	20.8[b]	19.6[b]	20.0[b]	18.2[b]
Cooperative State Research Service	3.7	3.7	3.8	3.8	3.4	3.4	3.0[c]	3.0[c]	2.8[c]	2.8[c]
Commerce	14.6	4.6	14.5	5.1	12.6	2.9	11.3	2.2	7.9	1.6
National Bureau of Standards	14.6	4.6	14.5	5.1	12.6	2.9	11.0	2.1	7.9	1.5
Defense	208.4	59.8	180.9	48.4	194.9	43.5	167.1	35.7	119.4	26.6
Air Force	42.1	19.8	34.5	14.1	32.3	12.9	24.8	10.4	24.0	10.0
Army	60.4	20.0	51.7	16.7	49.5	14.5	46.0	12.7	9.7	4.3
Navy	101.3	20.0	91.5	17.6	79.7	15.9	71.9	12.3	43.6	10.1
Energy	619.6	86.6	531.7	78.9	480.2	70.0	432.1	62.1	345.6	57.7
Environmental Protection Agency	2.6	2.6	5.3	5.3	2.9	2.9	2.3	2.3	1.8	1.8
Health & Human Services	57.8	52.1	55.9	50.4	53.2	48.0	53.7	47.4	40.7	36.7
National Institutes of Health	56.7	51.1	55.0	49.5	52.8	47.6	53 0	46.6	40.3	36.3
Interior	8.1	5.5	8.6	5.8	10.1	6.8	7.5	5.3	9.1	6.5
Geological Survey	2.6	1.8	2.8	1.9	3.0	2.0	2.6	1.7	2.6	1.7
National Aeronautics & Space Administration	404.4	5.5	316.4	4.1	268.9	6.6	309.0	5.2	292.5	5.3
National Science Foundation	282.0	89.6	268.8	85.4	254.8	81.5	198.6	66.4	197.1	60.3
Tennessee Valley Authority	3.7	3.7	3.4	3.4	3.1	3.1	3.1	3.1	2.7	2.7
Others	8.7	0	9.6	0.7	10.5	1.1	10.1	1.2	9.4	1.3
TOTAL	$1650.4	$348.7	$1432.0	$322.6	$1324.9	$298.2	$1220.6	$256.9	$1050.0	$224.8

a Estimated. b Agricultural R&D in Science & Education Administration. c Cooperative R&D in Science & Education Administration. **Note:** Fiscal years. **Source:** National Science Foundation

APPLIED RESEARCH: Chemistry this year gets lower share of funds for physical sciences

	Federal obligations ($ millions)									
	1983[a]		1982[a]		1981		1980		1979	
Department or agency	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Agriculture	$ 27.5	$ 25.6	$ 26.4	$ 24.5	$ 25.0	$ 22.7	$ 26.9	$ 24.9	$ 26.9	$ 25.0
Agricultural Research Service	19.0	17.6	17.4	16.1	16.2	14.6	20.0[b]	17.8[b]	19.3[b]	18.1[b]
Cooperative State Research Service	6.3	6.3	6.5	6.5	5.8	5.8	5.4[c]	5.4[c]	5.1[c]	5.1[c]
Commerce	31.3	8.4	30.1	7.7	30.5	8.9	27.4	7.3	27.8	7.3
National Bureau of Standards	25.0	7.5	24.1	6.8	24.4	7.5	21.3	6.0	21.9	6.1
Defense	599.3	68.2	506.7	62.5	335.2	47.2	243.4	42.5	237.0	59.5
Air Force	55.7	14.2	50.1	13.0	49.7	14.3	41.5	12.5	91.0	19.6
Army	78.9	38.4	75.7	37.6	58.6	24.6	54.3	24.2	80.6	26.8
Navy	149.9	15.3	129.2	11.6	98.5	8.1	59.0	5.3	62.6	6.2
Energy	451.9	16.1	407.8	137.3	390.2	13.7	360.0	22.2	317.7	14.6
Environmental Protection Agency	34.3	34.3	61.5	61.5	66.4	66.4	69.3	68.4	71.4	70.7
Health & Human Services	27.6	24.7	25.6	22.6	25.1	22.1	26.1	22.5	29.1	26.1
National Institutes of Health	26.3	23.1	25.4	22.3	24.8	21.8	25.4	21.8	28.8	25.9
Interior	5.5	4.6	5.4	4.5	7.3	5.3	6.4	4.4	6.6	5.3
Geological Survey	4.3	3.4	4.0	3.2	5.0	4.0	3.7	2.9	4.0	3.2
National Aeronautics & Space Administration	9.0	0.4	9.0	0.4	11.3	1.1	12.3	1.5	12.3	1.1
National Science Foundation	2.6	1.3	2.3	1.0	2.2	0.9	4.7	2.3	8.7	5.3
Others	6.7	0.5	3.2	0.5	2.4	0.4	3.5	1.6	5.3	3.9
TOTAL	$1195.9	$184.1	$1078.0	$322.5	$895.6	$188.7	$780.0	$197.6	$742.6	$218.8

a Estimated. b Agricultural R&D in Science & Educational Administration. c Cooperative R&D in Science & Education Administration. **Note:** Fiscal years. **Source:** National Science Foundation

OBLIGATIONS FOR PHYSICAL SCIENCE RESEARCH: Chemistry's share for energy work shrinks

	Federal obligations ($ millions)									
	1983[a]		1982[a]		1981		1980		1979	
Department or agency	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Agriculture	$ 68.0	$ 64.3	$ 63.2	$ 59.6	$ 58.7	$ 54.5	$ 52.6	$ 48.9	$ 50.6	$ 47.2
Agricultural Research Service	53.4	50.8	47.9	45.5	43.9	41.1	40.8[b]	37.4[b]	39.3[b]	36.3[b]
Cooperative State Research Service	10.0	10.0	10.2	10.2	9.2	9.2	8.4[c]	8.4[c]	7.9[c]	7.9[c]
Commerce	45.9	13.0	44.5	12.8	43.1	11.8	38.7	9.5	35.5	8.9
National Bureau of Standards	39.6	12.1	38.5	11.9	37.0	10.4	32.3	8.7	29.8	7.7
Defense	807.7	128.0	687.6	110.9	530.1	90.7	410.5	78.2	356.4	88.1
Air Force	97.8	33.9	84.5	27.2	82.1	27.2	66.3	22.9	120.1	29.6
Army	139.3	58.5	127.4	54.3	108.0	39.1	100.3	36.9	90.2	41.0
Navy	251.2	35.4	220.6	29.2	178.2	24.0	131.0	17.6	106.2	16.2
Energy	1071.5	102.7	939.5	216.2	870.4	83.7	792.1	84.3	663.4	72.3
Environmental Protection Agency	36.9	36.9	66.8	66.8	69.3	69.3	71.5	70.7	73.2	72.5
Health & Human Services	85.6	76.8	81.5	73.0	78.3	70.1	79.8	69.9	69.8	62.8
National Institutes of Health	83.0	74.2	80.4	71.9	77.7	69.4	78.3	68.4	69.2	62.1
Interior	13.7	10.1	14.1	10.3	17.4	12.0	13.9	9.8	15.7	11.8
Geological Survey	6.9	5.2	6.8	5.0	8.0	6.0	6.2	4.6	6.6	4.9
National Aeronautics & Space Administration	413.4	5.9	325.4	4.5	280.1	7.7	321.3	6.7	304.8	6.4
National Science Foundation	284.6	90.9	271.1	86.4	257.0	82.4	203.3	70.7	205.8	65.6
Tennessee Valley Authority	3.7	3.7	3.4	3.4	3.1	3.1	3.1	3.1	5.4	5.4
Others	15.3	0.5	13.0	1.2	13.0	1.6	13.8	2.7	12.0	2.6
TOTAL	$2546.3	$532.8	$2510.1	$645.1	$2220.5	$486.9	$2000.6	$454.5	$1792.6	$443.6

a Estimated. b Agricultural R&D in Science & Education Administration. c Cooperative R&D in Science & Education Administration. **Note:** Fiscal years. **Source:** National Science Foundation

UNIVERSITY RESEARCH: Bulk of federal money goes to life sciences

								Annual change	
Federal obligations, $ millions	1983[a]	1982[a]	1981	1980	1979	1978	1977	1982–83	1977–83
Engineering	$ 392.6	$ 368.5	$ 365.3	$ 323.7	$ 269.6	$ 240.9	$ 220.6	7%	10%
Chemical	23.3	21.2	21.9	20.3	19.2	24.5	17.1	10	5
Metallurgy and materials	83.4	74.1	69.5	57.3	52.3	49.2	46.9	13	10
Environmental sciences	300.5	284.0	280.3	297.0	275.5	226.5	205.2	6	7
Life sciences	2267.7	2208.8	2117.2	1984.7	1796.0	1605.2	1399.9	3	8
Mathematics and computer sciences	168.6	141.6	121.4	94.6	87.5	79.5	72.9	19	15
Physical sciences	593.0	545.1	525.2	461.0	402.8	366.6	326.1	9	10
Chemistry	208.5	192.0	193.5	159.5	140.1	123.5	115.8	9	10
Physics	325.7	291.7	274.5	246.1	214.7	198.7	167.0	12	12
Other sciences	284.0	270.1	297.5	302.7	285.6	253.0	228.6	5	4
TOTAL	$4006.4	$3818.1	$3706.9	$3463.6	$3117.0	$2771.7	$2453.3	5%	9%

a Estimated. **Note:** Fiscal years. **Source:** National Science Foundation

UNIVERSITY BASIC RESEARCH: Chemistry's share is 7% of total federal funds

								Annual change	
Federal obligations, $ millions	1983[a]	1982[a]	1981	1980	1979	1978	1977	1982–83	1977–83
Engineering	$ 278.3	$ 258.2	$ 237.3	$ 208.4	$ 164.0	$ 151.5	$ 139.3	8%	12%
Chemical	21.0	19.1	19.8	16.9	12.5	9.3	9.5	10	14
Metallurgy and materials	76.4	69.0	62.6	51.9	47.6	43.4	42.1	11	10
Environmental sciences	267.5	248.9	241.6	255.3	229.9	191.8	166.0	7	8
Life sciences	1423.2	1378.3	1314.6	1219.5	1140.1	926.9	809.8	3	10
Mathematics and computer sciences	132.8	119.4	102.6	79.8	69.0	65.3	56.6	11	9
Physical sciences	494.3	454.8	434.7	375.9	323.3	299.5	270.2	9	11
Chemistry	183.0	167.5	164.7	136.1	114.3	102.2	96.2	9	11
Physics	260.9	235.8	222.4	194.3	166.2	157.1	137.4	11	11
Other sciences	148.7	137.9	148.2	152.4	125.4	103.1	93.3	8	8
TOTAL	$2744.8	$2597.5	$2479.0	$2291.3	$2051.7	$1738.1	$1535.2	6%	10%

a Estimated. **Note:** Fiscal years. **Source:** National Science Foundation

Defense R&D budget to get a solid boost for fiscal 1984, but most NSF programs do well also

DEPARTMENT OF ENERGY R&D BUDGET: Holding its own in fiscal 1984

	1984					
$ Millions	Congressional appropriation	Administration request	1983[a]	1982	1981	% change 1983–84
Defense R&D	$ 714.5	$ 714.5	$ 641.5	$ 584.9	$ 508.1	11.4%
Nuclear	548.8	807.3	746.2	772.4	871.7	−26.4
General science and research	475.7	479.7	423.4	423.9	378.0	12.3
Magnetic fusion	394.4	392.7	368.6	295.1	256.3	7.0
Supporting research and technical analysis	311.6	313.6	272.7	269.6	240.4	14.3
Fossil energy	265.9[b]	94.0	217.5	417.7	818.7	22.2
Environment	211.3	197.3	206.1	213.6	206.7	2.5
Solar energy	174.4	86.4	201.4	252.4	451.2	−13.4
Conservation R&D	144.0[b]	71.0	152.7	152.3	248.8	−5.7
Electric energy systems and storage	44.2	26.9	42.9	58.3	85.1	3.0
Geothermal	29.5	13.5	30.4	41.3	126.3	−3.0
TOTAL	**$3314.3**	**$3196.9**	**$3303.4**	**$3481.5**	**$4191.3**	**0.3%**

a Estimate. b Based only on House action to date. **Note:** Fiscal years ending Sept. 30.

NSF BUDGET: Hefty increases for all but one program

	1984					
$ Millions	Congressional appropriation	Administration request	1983[a]	1982	1981	% change 1983–84
Mathematical and physical sciences	$ 361.1[b]	$ 364.3	$ 299.7	$272.8	$ 256.5	20.5%
Astronomical, atmospheric, earth, and ocean sciences	328.0[b]	334.9	276.1	259.9	258.3	18.8
Biological, behavioral, and social sciences	227.3	223.6	190.2	176.6	185.5	19.8
Engineering	119.8[b]	123.0	100.8	93.3	86.4	18.8
Antarctic program	102.1	102.1	83.2	68.5	67.4	22.7
Science and engineering education	75.0	39.0	30.0	20.9	70.7	150.0
Program development and management	65.0	66.0	65.3	63.2	59.2	—
Scientific, technological and international affairs	37.8	36.8	44.2	40.3	53.8	−14.5
Special foreign currency	2.6	2.6	3.1	3.6	4.0	−16.1
TOTAL	**$1318.7**	**$1292.3**	**$1092.6**	**$999.1**	**$1041.8**	**20.7%**

a Estimate. b Reflects one-third share of $20.8 million reduction. **Note:** Fiscal years ending Sept. 30

DEFENSE R&D BUDGET: Continues its surge upward

	1984					
$ Millions	Probable Congressional authorization[a]	Administration request	1983[b]	1982	1981	% change 1983–84
Air Force	$12,448.1	$13,652.3	$10,720.8	$ 8,659.6	$ 7,083.0	16.1%
Navy	7,629.0	8,182.4	6,129.1	5,844.4	4,974.8	24.5
Army	4,198.9	4,793.7	3,926.4	3,609.5	3,127.8	6.9
Defense agencies	2,758.5	2,996.9	2,271.5	1,745.6	1,341.0	21.4
TOTAL	**$27,034.5**	**$29,625.3**	**$23,047.8**	**$19,589.1**	**$16,526.6**	**17.3%**

a C&EN estimate based on House and Senate action to date. b Estimate. **Note.** Fiscal years ending Sept. 30.

NASA R&D BUDGET: Gets a modest 5% increase for the year ahead

$ Millions	1984 Congressional appropriation	1984 Administration request	1983[a]	1982	1981	% change 1983–84
Conduct of R&D	**$5801.8**	**$5708.5**	**$5542.8**	**$4786.9**	**$4332.4**	**4.6%**
Space transportation systems	3532.5	3498.0	3597.8	3104.8	2728.6	−1.8
Tracking and data acquisition	690.0	700.2	498.8	402.1	339.9	38.3
Physics and astronomy	564.6	514.6	441.0	322.4	323.7	28.0
Aeronautical research and technology	312.3	300.3	280.0	264.8	271.4	11.5
Space applications	292.0	289.0	351.0	324.3	331.5	−16.8
Planetary exploration	219.4	205.4	186.4	210.0	175.6	17.7
Space research and technology	138.0	138.0	123.0	111.0	110.7	12.2
Life sciences	59.0	59.0	55.7	39.5	42.2	5.9
Technology utilization	9.0	4.0	9.0	8.0	8.8	—
General reduction	−15.0	—	—	—	—	—
Research and program management	**1238.5**	**1247.5**	**1168.9**	**1183.3**	**1071.1**	**5.9**
Construction of facilities	**135.5**	**150.5**	**97.5**	**132.1**	**117.0**	**39.0**
TOTAL	**$7175.8**	**$7106.5**	**$6809.2**	**$6102.3**	**$5520.5**	**5.3%**

a Estimate. **Note:** Fiscal years ending Sept. 30.

EPA R&D BUDGET: Substantially higher than requested by the Administration

$ Millions	1984 Congressional appropriation	1984 Administration request	1983[a]	1982	1981	% change 1983–84
Air	$ 32.3	$ 27.3	$ 35.4	$ 38.4	$ 59.0	−8.8%
Solid/hazardous waste	26.3	17.0	21.2	21.9	28.3	17.4
Energy	22.0	20.0	22.4	57.6	84.1	−2.0
Interdisciplinary	16.0	16.0[b]	3.5	4.5	6.1	—
Drinking water	14.5	12.0	14.3	22.4	21.8	1.4
Toxic substances	12.9	11.9	14.2	20.9	30.0	9.1
Water quality	11.4	6.4	12.2	31.7	49.9	1.6
Pesticides	1.7	1.7	2.1	2.2	7.9	−19
Radiation	1.0	0.02	0.5	0.9	2.4	100
TOTAL	**$143.1[c]**	**$112.3**	**$125.8**	**$200.5**	**$289.5**	**13.7%**

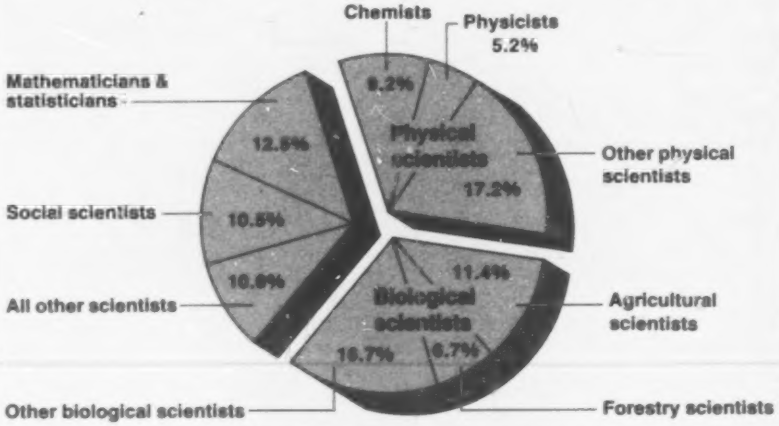
a Estimate. b Not an increase in total budget, reflects consolidation of other programs into the interdisciplinary program. c Includes $5 million to be allocated to high-priority programs at agency's discretion. **Note:** Fiscal years ending Sept. 30.

NIH BUDGET: Administration is seeking a very slight increase

$ Millions	1984[a]	1983[b]	1982	1981	1980	% change 1983–84
National Institutes	**$3769.7**	**$3689.9**	**$3392.0**	**$3306.3**	**$3044.9**	2.1%
Cancer	986.7	983.6	943.0	947.3	898.0	0.3
Heart, Lung & Blood	637.7	622.7	559.6	549.7	527.1	2.4
Arthritis, Diabetes & Digestive & Kidney Disease	426.4	412.2	368.2	369.5	340.1	3.4
General Medical Science	383.1	369.6	355.4	329.4	312.3	3.6
Neurological & Communicative Disorders & Stroke	301.5	295.7	265.5	252.6	214.3	1.9
Allergy & Infectious Diseases	289.4	273.6	235.8	232.2	214.7	5.7
Child Health & Human Development	256.6	253.6	226.2	220.7	208.3	1.2
Environmental Health Sciences	165.9	164.4	154.1	140.0	83.6	0.9
Eye	142.3	141.6	130.4	118.0	109.6	0.5
Aging	99.4	94.0	81.8	75.7	69.7	0.5
Dental Research	80.7	78.9	72.0	71.2	67.2	2.1
Research Resources	**201.8**	**213.8**	**184.1**	**175.7**	**169.1**	**−5.6**
National Library of Medicine	**49.6**	**47.1**	**44.8**	**44.7**	**43.9**	**5.3**
Office of the Director	**26.7**	**25.7**	**23.6**	**21.7**	**20.8**	**3.9**
Research facilities	**19.9**	**29.1**	**9.9**	**11.7**	**13.9**	**−31.6**
John E. Fogarty Center	**9.2**	**10.3**	**9.2**	**9.1**	**8.6**	**−10.7**
TOTAL	**$4076.9**	**$4015.9**	**$3663.6**	**$3569.2**	**$3301.2**	**1.5%**

a Administration request. b Estimate. **Note:** Fiscal years ending Sept. 30.

About 9% of all government scientists are chemists



1981 total federal scientists = 86, 630[a]

[a] As of October 1981. **Source:** National Science Foundation

SCIENTISTS AND ENGINEERS BY AGENCY: Health and defense are leading fields for chemists

Department or agency	Physical scientists	Chemists	Physicists	Engineers	Chemical engineers	Other scientists	Total scientists and engineers
Agriculture[a]	1,443	942	31	3,306	59	20,573	25,322
Commerce	3,833	335	567	748	18	2,947	7,528
Defense	8,591	1,998	3,262	56,473	726	12,653	77,717
Air Force	1,094	295	490	10,119	41	1,361	12,574
Army	3,108	874	870	20,355	390	4,656	28,119
Navy	3,885	735	1,871	24,651	290	2,674	31,210
Others	504	94	31	1,348	5	3,962	5,814
Energy	571	0	113	2,813	181	599	3,983
Environmental Protection Agency	1,632	599	17	1,616	127	894	4,144
Health & Human Services	2,157	1,999	90	473	25	4,550	7,180
Interior	5,007	457	62	3,058	73	6,908	14,973
National Aeronautics & Space Administration	1,300	80	269	8,819	20	783	10,902
Tennessee Valley Authority	245	112	0	3,922	172	376	4,543
Transportation	134	34	9	4,653	16	701	5,488
Veterans Administration	687	614	44	992	0	2,353	4,032
Others	1,775	778	37	4,039	42	5,913	11,727
TOTAL	27,375	7,948	4,501	90,914	1,459	59,250	177,539

[a] Estimated. **Note:** Data as of October 1981. **Source:** National Science Foundation

FEDERAL SCIENTISTS AND ENGINEERS: Number of chemists lowest since 1974

Thousands	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Physical scientists	27.4	27.6	27.6	27.5	27.1	27.1	26.7	26.3	26.4	27.4	30.4
Chemists	7.9	8.1	8.1	8.3	8.0	8.1	8.0	7.8	8.0	8.4	8.3
Physicists	4.5	4.6	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.8	5.4
Engineers	90.9	89.6	88.8	89.2	87.8	87.0	86.6	82.5	84.3	87.0	84.2
Chemical	1.4	1.5	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.6	1.5
Other scientists	59.3	60.8	58.3	57.2	54.3	51.6	50.6	48.8	48.4	50.1	48.7
TOTAL	177.5	178.0	174.7	173.9	169.2	165.7	163.9	157.6	159.1	164.5	163.3

Note: As of October of each year. **Source:** National Science Foundation

SECTION 3

R&D

Industry

Industrial R&D maintains rapid growth

Chemical producers have been boosting R&D spending more rapidly than industry as a whole, but this year's budgets point to a slackening pace

TOTAL FUNDS FOR INDUSTRIAL R&D: Spending is rising relatively fast in chemical industry

$ Millions	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Chemicals and allied products	**$ 6,250**	**$ 5,325**	**$ 4,636**	**$ 4,038**	**$ 3,580**	**$ 3,202**	**$ 3,017**	**$ 2,727**	**$ 2,450**	**$ 2,116**	**$ 1,932**	17%	12%
Industrial chemicals	3,000	2,553	2,197	1,962	1,798	1,668	1,524	1,391	1,299	1,119	1,031	18	11
Drugs	2,400	2,022[a]	1,777	1,517	1,308	1,117	1,091	981	807	698	607	19	15
Other chemicals	850	750[a]	662	559	474	417	401	354	344	299	294	13	11
Other industries	**51,600**	**46,505**	**39,869**	**34,188**	**29,724**	**26,623**	**23,980**	**21,460**	**20,437**	**19,133**	**17,620**	11	11
TOTAL	**$57,850**	**$51,830**	**$44,505**	**$38,226**	**$33,304**	**$29,825**	**$26,997**	**$24,187**	**$22,887**	**$21,249**	**$19,552**	12%	11%

a C&EN estimates. **Source:** National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Little support for chemical industry's labs

$ Millions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Chemicals and allied products	**$ 425[a]**	**$ 383**	**$ 372**	**$ 346**	**$ 330**	**$ 295**	**$ 266**	**$ 236**	**$ 214**	**$ 203**	**$ 189**	11%	8%
Industrial chemicals	400[a]	367	341	345	325	281	249	218	194	183	171	9	9
Drugs and other chemicals	25[a]	16	31	1	5	14	17	18	20	20	18	56	3
Other industries	**18,100[a]**	**16,085**	**13,657**	**12,172**	**10,859**	**10,190**	**9295**	**8369**	**8006**	**7942**	**7828**	13	9
TOTAL	**$18,525**	**$16,468**	**$14,025**	**$12,518**	**$11,189**	**$10,485**	**$9561**	**$8605**	**$8220**	**$8145**	**$8017**	12%	9%

a C&EN estimates. **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Chemical firm's outlays doubled in past five years

$ Millions	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Chemicals and allied products	**$ 5,825[a]**	**$ 4,942**	**$ 4,264**	**$ 3,692**	**$ 3,250**	**$ 2,907**	**$ 2,751**	**$ 2,490**	**$ 2,236**	**$ 1,913**	**$ 1,741**	18%	13%
Industrial Chemicals	2,600[a]	2,186	1,856	1,617	1,473	1,387	1,275	1,173	1,105	936	860	19	12
Drugs and other chemicals	3,225[a]	2,756	2,408	2,075	1,777	1,520	1,476	1,317	1,131	977	881	17	14
Other industries	**33,500[a]**	**30,420**	**26,212**	**22,016**	**18,865**	**16,433**	**14,685**	**13,092**	**12,431**	**11,191**	**9,794**	10	13
TOTAL	**$39,325**	**$35,362**	**$30,476**	**$25,708**	**$22,115**	**$19,340**	**$17,436**	**$15,582**	**$14,667**	**$13,104**	**$11,535**	11%	13%

a C&EN estimates. **Source:** National Science Foundation

BASIC RESEARCH IN INDUSTRY: Chemical industry does about a third of total

$ Millions	1981	1979	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Chemicals and allied products	$ 539	$ 366	$337	$333	$298	$288	$236	$214	$216	$207	$208	$202
Industrial chemicals	335	197	163	149	136	129	111	107	110	89	121	126
Drugs	180	143	134	129	114	107	90	78	77	93	67	60
Other chemicals	24	26	40	55	48	52	35	29	29	25	20	16
Other industries	1102	792	574	484	431	411	395	379	374	395	410	440
TOTAL	$1641	$1158	$911	$817	$729	$699	$631	$593	$590	$602	$618	$642

Note: No data for 1978 and 1980. **Source:** National Science Foundation

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APPLIED RESEARCH IN INDUSTRY: For chemical firms, four times bigger than basic research

$ Millions	1981	1979	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Chemicals and allied products	$ 2,263	$1726[a]	$1347[a]	$1226	$1102	$ 941	$ 841	$ 745	$ 707	$ 660	$ 666	$ 603
Industrial chemicals	1,113	881[a]	605[a]	522	463	562	489	437	436	423	425	385
Drugs	na	654[a]	486[a]	472	426	266	248	206	184	167	160	144
Other chemicals	na	191[a]	256[a]	231	213	113	104	102	87	70	81	74
Other industries	8,449	5499[a]	4289	3909	3474	3219	2898	2726	2677	2739	2621	2521
TOTAL	$10,712	$7225	$5636	$5135	$4576	$4160	$3739	$3471	$3384	$3399	$3287	$3124

[a] Estimates. **Note:** No data for 1978 and 1980. **na** = not available. **Source:** National Science Foundation

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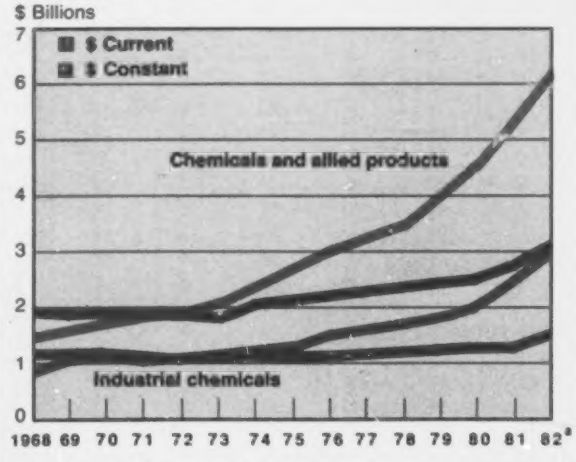
DEVELOPMENT IN INDUSTRY: Accounts for largest share of total R&D funds

$ Millions	1981	1979	1677	1976	1975	1974	1973	1972	1971	1970	1969	1968
Chemicals and allied products	$ 2,523	$ 1,946[a]	$ 1,518	$ 1,472	$ 1,330	$ 1,162	$ 999	$ 945	$ 872	$ 876	$ 845	$ 841
Industrial chemicals	1,105	947[a]	684[a]	670	604	600	520	487	464	494	694	507
Drugs	962	651[a]	513[a]	494	444	347	292	271	226	208	202	186
Other chemicals	456	348[a]	321[a]	310	284	221	188	187	182	174	147	148
Other industries	36,954	27,897[a]	21,760[a]	19,280	17,539	16,400	15,563	14,388	13,446	13,158	13,568	12,862
TOTAL	$39,477	$29,843	$23,278	$20,752	$18,869	$17,562	$16,562	$15,333	$14,318	$14,034	$14,413	$13,703

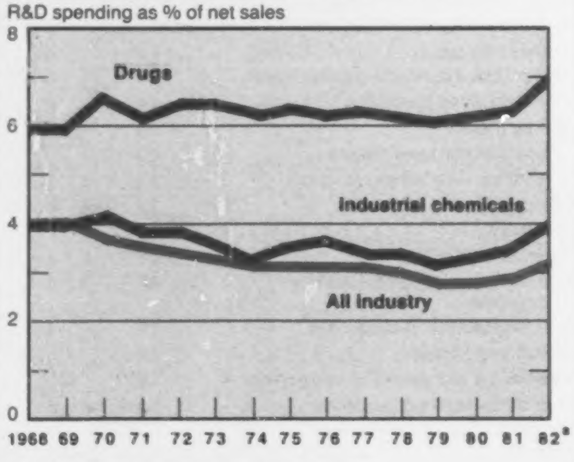
[a] Estimates. **Note:** No data for 1978 and 1980. **Source:** National Science Foundation

Chemical industry keeps R&D outlays ahead of inflation



a C&EN estimates. **Source:** National Science Foundation

R&D's share of industry sales rises as sales stagnate in recent recession



a C&EN estimates. **Source:** National Science Foundation

APPLIED R&D BY ALL INDUSTRY ON CHEMICALS: Biggest share devoted to drugs

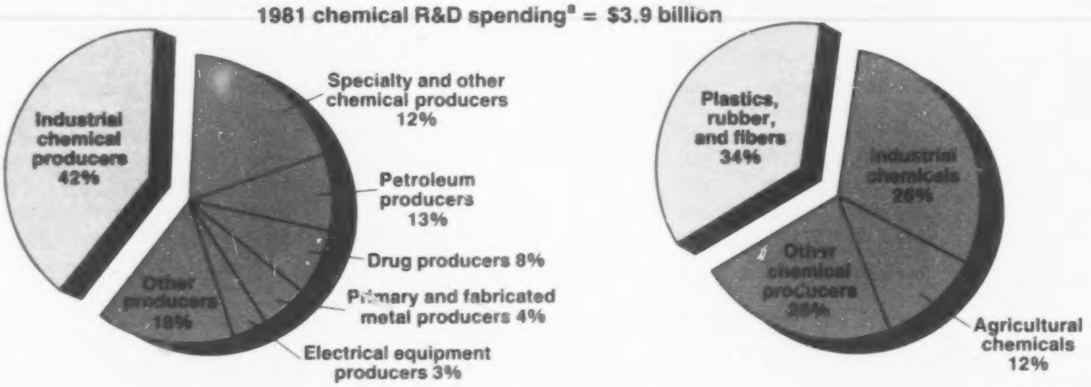
$ Millions	1981	1979	1977	1976	1975	1974	1973	1972	1971	1970	1969	1968
Industrial Chemicals	$1020	na	$ 822	$ 728	$ 665	$ 589	$ 489	$ 451	$ 457	$ 442	$ 417	$ 396
Plastics, rubber, and fibers	1315	$ 881	747	674	588	589	511	453	511	521	482	466
Agricultural chemicals	487	292	236	205	176	137	114	108	130	126	104	99
Other chemicals	1081	na	220	246	198	248	229	238	218	223	210	207
Drugs	1837	1089	959	883	783	683	605	531	535	474	417	375
TOTAL	**$5740**	**$3648**	**$2984**	**$2736**	**$2410**	**$2246**	**$1948**	**$1781**	**$1851**	**$1786**	**$1630**	**$1543**

na = not available. **Note:** No data for 1978 and 1980. **Source:** National Science Foundation

Industrial chemical producers do more than 40% of R&D on chemicals . . .

. . . and biggest slice of chemical R&D involves polymers

1981 chemical R&D spending[a] = $3.9 billion



a Excludes basic research and research on drugs. **Source:** National Science Foundation

APPLIED R&D ON CHEMICALS AND DRUGS: Outside chemical industry, oil firms do most

	Product field ($ millions)									
	1981		1979		1977		1976		1975	
Industry	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs	Chemicals	Drugs
Chemicals and allied products	**$2406**	**$1719**	**$1604**	**$1020**	**$1327**	**$903**	**$1192**	**$817**	**$1158**	**$681**
Industrial chemicals	[illegible]18	203	1086	138	806	101	711	84	807	83
Drugs	304	1460	205	840	131	756	130	703	84	567
Other chemicals	484	55	313	42	390	46	351	30	267	31
Petroleum refining	520	0	283	a	192	7	169	4	170	4
Rubber products	a	0	75	0	44	a	31	a	34	a
Stone, clay, and glass products	a	7	37	0	34	0	31	5	22	0
Food and kindred products	45	a	28	a	26	a	25	5	23	19
Textiles and apparel	a	0	a	0	a	0	a	0	11	a
Lumber, wood products, and furniture	15	0	5	0	10	0	8	0	8	0
Paper and allied products	46	0	36	0	22	a	13	a	16	a
Primary metals	79	0	a	0	55	a	47	0	24	a
Ferrous metals and products	23	0	a	0	14	0	13	0	11	a
Nonferrous metals and products	57	0	a	0	41	a	34	0	12	0
Fabricated metal products	79	0	65	a	47	3	42	4	20	6
Machinery	92	0	26	0	24	a	15	a	28	a
Electrical equipment	124	a	62	a	49	4	56	6	50	a
Motor vehicles and motor vehicle equipment	97	0	68	0	48	0	42	0	a	0
Other transportation equipment	22	1	19	0	15	0	a	0	a	0
Aircraft and missiles	52	0	25	0	15	0	27	0	35	a
Professional and scientific instruments	a	100	65	54	43	35	37	30	31	42
Other manufacturing industries	12	0	26	0	12	0	10	0	11	0
Nonmanufacturing industries	77	0	a	a	58	a	62	a	24	a
TOTAL	**$3903**	**$1837**	**$2559**	**$1089**	**$2024**	**$959**	**$1837**	**$877**	**$1703**	**$760**

a Not separately available but included in total. **Note:** No data for 1978 and 1980. **Source:** National Science Foundation

COMPANY R&D SPENDING: Most budgets have been increased this year, if only moderately

$ Millions	1983[a]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973
Air Products	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24	$ 19	$ 16	$ 11	$ 8
American Cyanamid	200	181	164	142	124	108	96	83	73	64	52
Celanese	100	102	104	94	92	83	77	70	64	58	49
Diamond Shamrock	46	48	53	45	37	32	26	24	20	14	12
Dow Chemical	480	460	404	314	269	232	203	188	167	149	118
Du Pont[b]	890	790	575	485	415	377	367	353	336	344	286
Ethyl	39	39	38	34	29	26	28	25	28	25	22
W. R. Grace	71	62	55	45	42	37	32	28	30	32	28
Hercules	68	71	61	53	47	40	37	35	30	30	25
Monsanto	284	256	221	204	161	136	132	114	116	87	82
Olin	48[c]	47	39	31	26	25	25	25	24	19	na
Pennwalt	34	31	27	24	22	23	21	19	16	14	13
Rohm & Haas	94[c]	92	77	67	54	49	45	43	45	39	32
Stauffer Chemical	64	62	51	44	37	34	33	29	24	20	17
Union Carbide	240	240	201	166	161	156	156	143	120	94	77
TOTAL	**$2698**	**$2518**	**$2102**	**$1778**	**$1540**	**$1381**	**$1302**	**$1198**	**$1109**	**$1000**	**$821**
ANNUAL CHANGE	**7%**	**20%**	**18%**	**15%**	**12%**	**6%**	**9%**	**8%**	**11%**	**20%**	**5%**

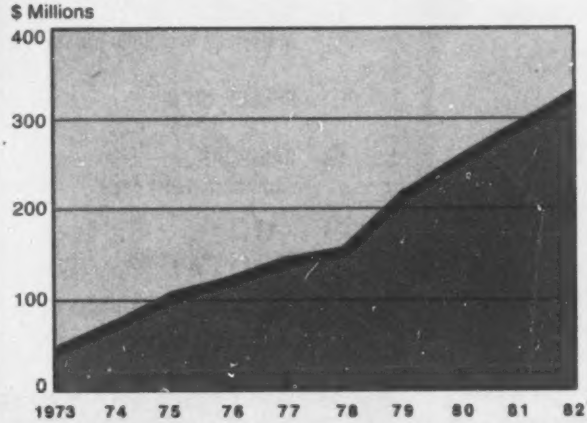
a Planned. b Excludes Conoco. c C&EN estimate. **Source:** Company data

R&D BY U.S. COMPANIES ABROAD: Chemical firms continue to boost spending outside U.S.

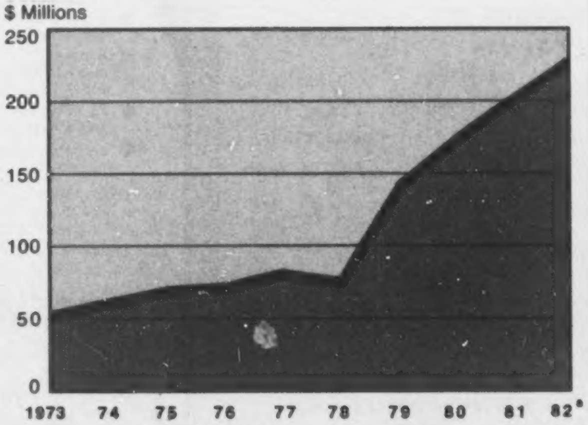
										Annual change	
$ Millions	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1981–82	1974–82
Chemicals and allied products	$ 700	$ 651	$ 603	$ 500	$ 395	$ 332	$ 312	$ 269	$ 208	8%	16%
Industrial and other chemicals	300	275	245	199	151	133	108	85	82	9	18
Drugs	400	376	357	301	244	199	204	184	126	6	16
Other industries	2600	2506	2562	2254	1814	1545	1347	1185	1092	4	11
TOTAL	$3300	$3157	$3165	$2754	$2209	$1877	$1659	$1454	$1300	5%	12%

a C&EN estimates. **Source:** National Science Foundation

Chemical industry's spending on energy R&D has tripled since 1975 . . .

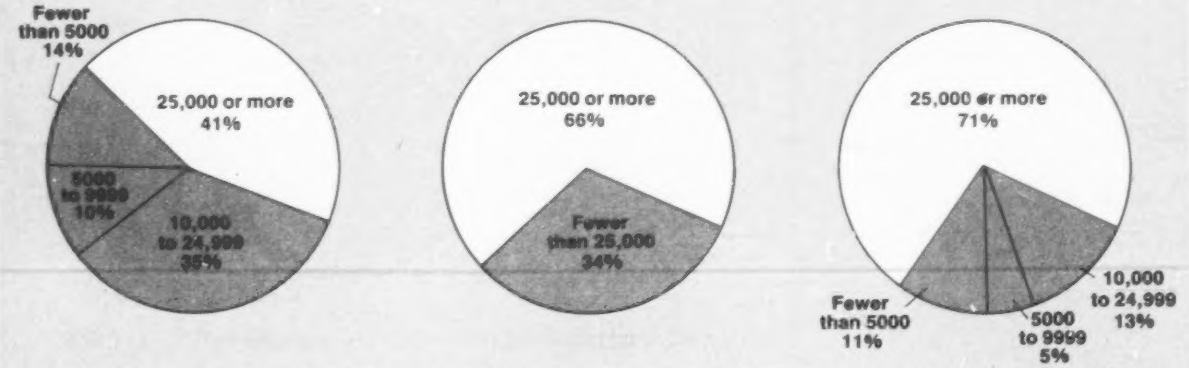


. . . as have its outlays for pollution control R&D



a C&EN estimates. **Source:** National Science Foundation

Biggest share of R&D funds is spent by companies with 25,000 or more employees



Total 1981 chemicals and allied products R&D funds = $5.3 billion

Total 1981 industrial chemicals R&D funds = $2.6 billion

Total 1981 industry R&D funds = $51.8 billion

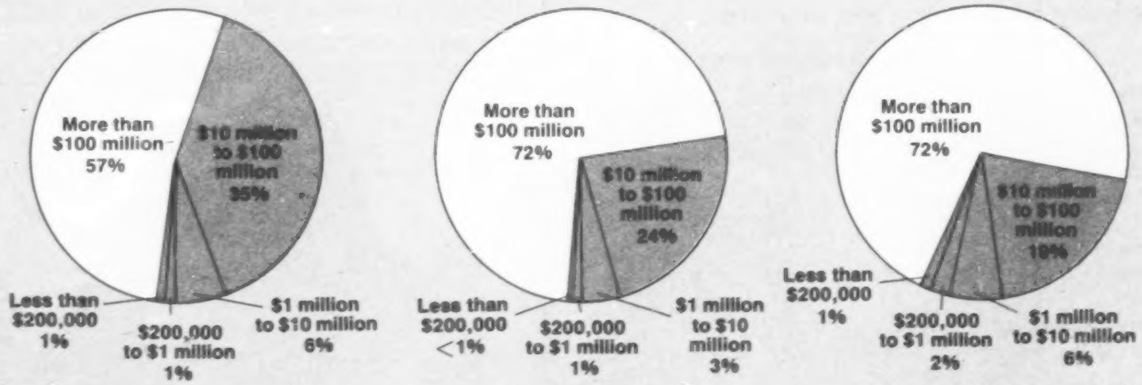
Note: Ranges indicate company's number of employees in 1981. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Big increase in 1982 for chemical industry

Thousands[a]	1982	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972
Chemicals and allied products	60.0	54.7	51.4	50.0	48.3	46.4	44.4	45.2	41.8	40.9	41.0
Industrial chemicals	24.3	21.6	20.9	21.4	21.3	20.6	20.1	21.1	19.1	19.1	19.1
Drugs	25.3	23.3	21.6	20.9	19.5	17.8	16.6	15.6	14.0	13.0	13.1
Other chemicals	10.4	9.8	8.9	7.9	7.5	8.0	7.8	8.5	8.7	8.8	8.8
Other industries	451.6	433.1	408.6	373.9	356.1	336.4	320.0	318.1	318.2	316.8	309.2
TOTAL	511.6	487.8	460.0	423.9	404.4	382.8	364.4	363.3	360.0	357.7	350.2

[a] Full-time equivalent. **Source:** National Science Foundation

More than 50% of R&D spending is by firms with budgets of more than $100 million



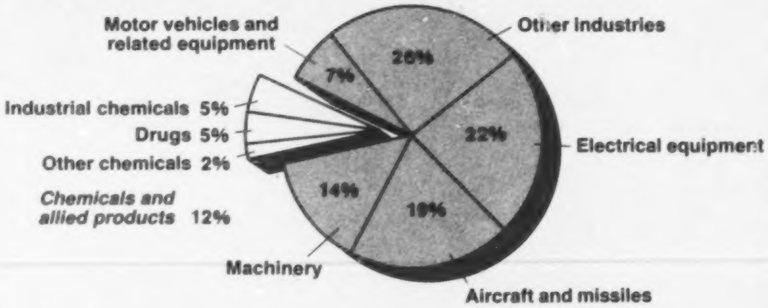
Total 1981 chemicals and allied products R&D funds = $5.3 billion

Total 1981 industrial chemicals R&D funds = $2.6 billion

Total 1981 industry R&D funds = $51.8 billion

Note: Ranges indicate size of company's 1981 R&D program. **Source:** National Science Foundation

Makers of electrical equipment and aircraft employ more than 40% of R&D scientists and engineers



1982 total industrial R&D scientists and engineers[a] = 511,600

a Full-time equivalent. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Ratio is high for chemical firms

	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
Chemicals and allied products	**45**	**43**	**42**	**43**	**42**	**40**	**41**	**40**	**39**	**39**	**41**	**39**
Industrial chemicals	39	36	36	38	38	36	38	37	36	34	35	35
Drugs	65	62	62	65	62	64	59	57	57	60	65	65
Other chemicals	34	32	27	27	29	28	29	30	29	31	31	30
All industry	**29**	**28**	**27**	**27**	**27**	**27**	**26**	**25**	**24**	**24**	**26**	**26**

Source: National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: Doubled in past decade

$ Thousands	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971
Chemicals and allied products	**$ 92.7**	**$ 84.6**	**$76.1**	**$71.7**	**$68.4**	**$66.5**	**$60.9**	**$56.3**	**$51.1**	**$47.1**	**$43.7**
Industrial chemicals	111.4	101.8	92.4	84.3	79.2	74.7	67.5	63.5	58.6	54.0	49.2
Drugs	a	76.3	69.9	63.8	64.4	63.4	60.9	54.3	51.5	46.5	43.2
Other chemicals	a	67.5	64.4	60.5	53.1	50.8	43.2	45.3	34.0	33.4	35.5
All industry	**103.7**	**93.9**	**86.8**	**79.9**	**76.1**	**72.2**	**66.5**	**63.3**	**59.2**	**55.3**	**51.1**

a Not separately available but included in total. **Source:** National Science Foundation

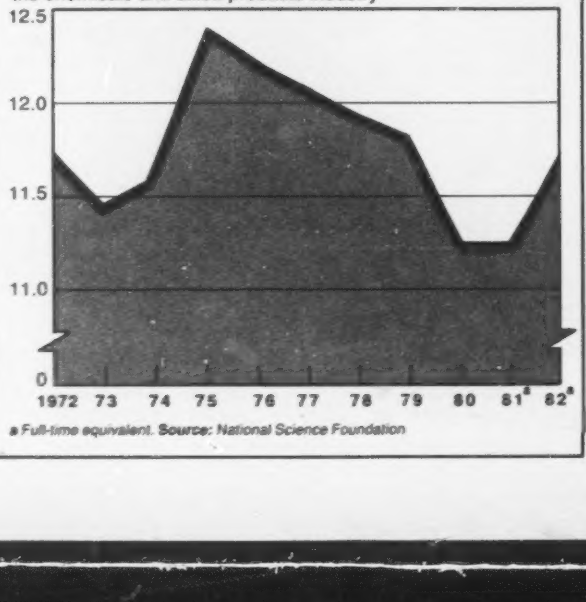
CHEMISTS IN INDUSTRY: Almost half are employed by chemical and drug firms

	% of industrial chemicals			
Industry	All chemists	B.S.	M.S.	Ph.D.
Chemical	31	25	27	38
Pharmaceutical	18	16	21	18
Petroleum	7	6	5	8
Coatings	6	9	7	4
Food	4	5	5	3
Metals and minerals	3	4	3	2
Rubber	2	4	3	1
Paper	2	1	2	2
Other manufacturing	20	22	19	19
Nonmanufacturing	7	8	8	5

Source: 1983 ACS survey

Share of scientists, engineers in chemical industry reversed six-year drop in 1982

% of total industrial R&D scientists and engineers[a] in the chemicals and allied products industry



a Full-time equivalent. **Source:** National Science Foundation

Growth is modest for academic spending on R&D

Small increases in funding from government agencies make last year's rise in outlays the smallest in a decade

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CHARACTER OF UNIVERSITY R&D SPENDING: Increases were small in 1982 across the board

$ Millions	1982[a]	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Basic research	$4700	$4559	$4020	$3607	$3172	$2797	$2548	$2410	$2154	$2053	$2022	3%	9%
Applied research	1920	1857	1687	1463	1213	1068	1015	851	736	713	524	3	14
Development	390	377	343	284	236	200	164	148	133	118	84	3	17
TOTAL	**$7010**	**$6793**	**$6050**	**$5354**	**$4621**	**$4065**	**$3727**	**$3409**	**$3023**	**$2884**	**$2630**	3%	10%

a Estimated. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Only industry provided a substantial increase last year

$ Millions	1982[a]	1981	1980	1979	1978[b]	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Federal government	$4695	$4549	$4093	$3594	$3057	$2726	$2512	$2288	$2032	$1985	$1795	3%	10%
State and local governments	548	538	493	469	413	373	363	332	307	295	269	2	7
Industry	320	285	235	193	170	139	123	113	96	84	74	12	16
Institutional funds	992	974	821	725	622	514	445	417	370	318	305	2	13
Other sources	455	447	408	373	359	313	284	259	218	202	187	2	9
TOTAL	**$7010**	**$6793**	**$3050**	**$5354**	**$4621**	**$4065**	**$3727**	**$3408**	**$3023**	**$2884**	**$2630**	3%	10%

a Estimated. b Estimated, based on data from Ph.D.-granting institutions only. **Note:** Data for institutional fiscal year. **Source:** National Science Foundation

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FIELDS OF UNIVERSITY R&D SPENDING: Outlays for chemistry have nearly tripled since 1972

$ Millions	1982[a]	1981	1980	1979	1978[b]	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Physical sciences	**$ 785**	**$ 764.0**	**$ 676.9**	**$ 601.2**	**$ 496.4**	**$ 423.5**	**$ 379.4**	**$ 350.3**	**$ 333.5**	**$ 328.3**	**$ 324.2**	3%	9%
Chemistry	300	283.7	243.5	205.8	183.1	159.4	140.1	120.7	115.8	113.7	108.1	6	11
Physics	380	356.6	322.0	292.0	235.1	201.7	183.1	173.5	169.3	167.0	159.1	1	9
Engineering	**980**	**957.2**	**862.8**	**767.9**	**601.1**	**498.5**	**431.7**	**380.9**	**346.9**	**333.1**	**341.4**	2	11
Total R&D spending	**7010**	**6793.3**	**6049.5**	**5354.5**	**4621.3**	**4065.1**	**3727.3**	**3408.7**	**3022.6**	**2884.0**	**2630.4**	3	10

a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

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FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Chemistry accounts for nearly 5%

$ Millions	1982[a]	1981	1980	1979	1978[b]	1977	1976	1975	1974	1973	1972	Annual change 1981–82	Annual change 1972–82
Physical sciences	**$ 635**	**$ 617.6**	**$ 554.4**	**$ 490.7**	**$ 392.3**	**$ 338.8**	**$ 305.4**	**$ 285.0**	**$ 270.2**	**$ 268.4**	**$ 261.0**	3%	9%
Chemistry	225	215.9	189.2	156.5	138.0	121.5	107.9	92.7	88.7	86.6	82.6	4	11
Physics	315	308.3	279.7	252.5	199.2	171.9	156.1	149.9	146.5	145.4	136.3	2	9
Engineering	**680**	**661.3**	**594.6**	**526.4**	**407.5**	**336.7**	**290.5**	**259.4**	**239.3**	**238.1**	**252.9**	3	10
Total R&D spending	**4695**	**4549.3**	**4092.5**	**3594.3**	**3057.2**	**2725.8**	**2511.6**	**2288.1**	**2032.2**	**1985.4**	**1795.0**	3	10

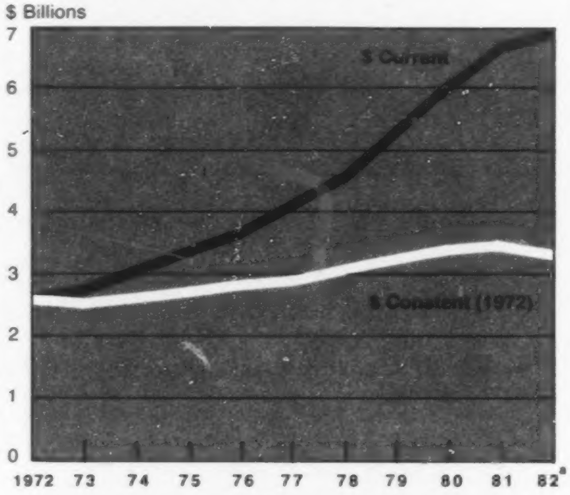
a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **Note.** Data for institutional fiscal years. **Source:** National Science Foundation

TOP 12 UNIVERSITIES IN R&D SPENDING: Johns Hopkins leads by a large margin

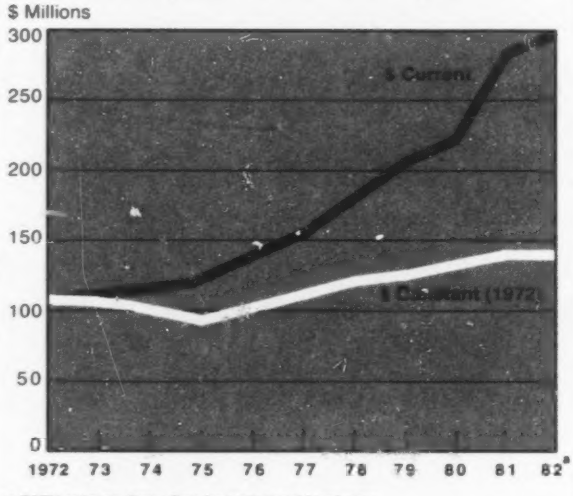
$ Millions, fiscal 1981	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math and computer sciences	Other sciences[b]	Total
Johns Hopkins University	$49.6	$4.1	$64.0	$28.8	$73.2	$45.0	$ 9.9	**$270.5**
Massachusetts Institute of Technology	57.1	8.2	73.4	9.6	24.0	10.6	9.5	**184.3**
University of Wisconsin, Madison	13.4	4.1	13.2	13.9	78.6	4.8	23.7	**147.5**
University of California, San Diego	20.3	4.4	1.2	59.1	53.3	1.5	2.5	**137.8**
University of Michigan	9.5	2.0	17.6	12.2	57.8	2.4	33.5	**133.1**
University of Minnesota	8.2	4.3	12.0	2.5	99.5	1.4	9.5	**133.1**
Stanford University	19.7	5.6	41.2	2.5	52.5	7.9	5.9	**129.8**
University of Washington	6.1	1.5	6.2	16.8	77.5	2.3	16.0	**124.8**
Cornell University	19.3	4.6	18.7	3.6	70.4	2.0	9.1	**123.3**
Harvard University	14.7[c]	6.1[c]	1.8[c]	5.6[c]	76.4[c]	1.7[c]	11.5[c]	**111.7[c]**
University of Pennsylvania	10.0	3.4	4.8	0.9	65.2	4.7	18.9	**104.4**
Columbia University, main division	9.1	3.6	5.1	17.1	62.1	0.6	6.7	**100.7**

a Included in physical sciences. b Includes social sciences, psychology, and other sciences not listed separately. c Estimated. **Source:** National Science Foundation

Inflation has eroded gains in spending for all academic R&D recently . . .



. . . and chemical R&D spending, in real terms, barely held its own last year



a C&EN estimate. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

TOP 12 UNIVERSITY R&D CENTERS:[a] Physical sciences get half of total R&D funds

$ Millions, fiscal 1981	Physical sciences	Engineering	Environmental sciences	Life sciences	Total[b]
Lawrence Livermore National Lab	$356.1	$ 48.4	$30.1	$ 3.6	**$466.8**
Los Alamos National Lab	211.3	142.8	8.8	18.1	**442.1**
Jet Propulsion Lab	70.8	165.8	24.3	0	**411.4**
Argonne National Lab	81.6	148.6	60.4	20.6	**314.2**
Brookhaven National Lab	90.9	28.7	9.2	17.1	**150.8**
Lincoln Lab	28.4	102.5	0	0	**147.1**
Lawrence Berkeley Lab	75.1	11.9	23.6	20.7	**135.6**
Plasma Physics Lab	128.5[c]	0	0	0	**128.5[c]**
Fermi National Accelerator Lab	95.5	0	0	0	**95.5**
Stanford Linear Accelerator Center	66.5	0	0	0	**66.5**
National Center for Atmospheric Research	6.6	0	27.6	0	**34.2**
Ames Laboratory	12.7	6.4	0.2	0	**19.7**

a Data for university-administered federally funded R&D centers. b Includes sciences not listed separately. c Estimated. **Source:** National Science Foundation

ACADEMIC SCIENTISTS AND ENGINEERS: Total number of chemists rose to 18,200

Thousands of scientists and engineers[a]	1982	1981	1980	1978	1977	1976	1975
TOTAL							
Physical scientists	**34.4**	**34.1**	**33.6**	**32.8**	**32.1**	**31.4**	**30.8**
Chemists	18.2	18.1	17.6	17.7	17.1	16.6	16.2
Physicists	13.0	12.9	13.0	12.8	12.5	12.2	12.3
Engineers	**36.4**	**34.8**	**33.7**	**31.0**	**30.1**	**28.5**	**27.9**
Chemical	2.3	2.3	2.4	2.0	1.9	1.9	1.9
Other scientists	**278.0**	**264.6**	**256.8**	**243.8**	**235.5**	**228.3**	**220.2**
TOTAL	**348.8**	**333.4**	**324.1**	**307.6**	**297.8**	**288.2**	**278.9**
FULL TIME ONLY							
Physical scientists	**28.5**	**28.2**	**28.0**	**27.9**	**27.6**	**27.1**	**26.7**
Chemists	14.8	14.8	14.3	14.7	14.5	14.1	13.8
Physicists	11.2	11.0	11.3	11.2	11.1	10.8	10.9
Engineers	**28.0**	**27.0**	**26.5**	**24.7**	**24.1**	**22.9**	**22.6**
Chemical	1.9	1.9	1.9	1.7	1.7	1.6	1.6
Other scientists	**210.6**	**203.7**	**200.4**	**189.5**	**184.5**	**179.8**	**174.1**
TOTAL	**267.1**	**258.8**	**254.9**	**242.1**	**236.2**	**229.8**	**223.3**

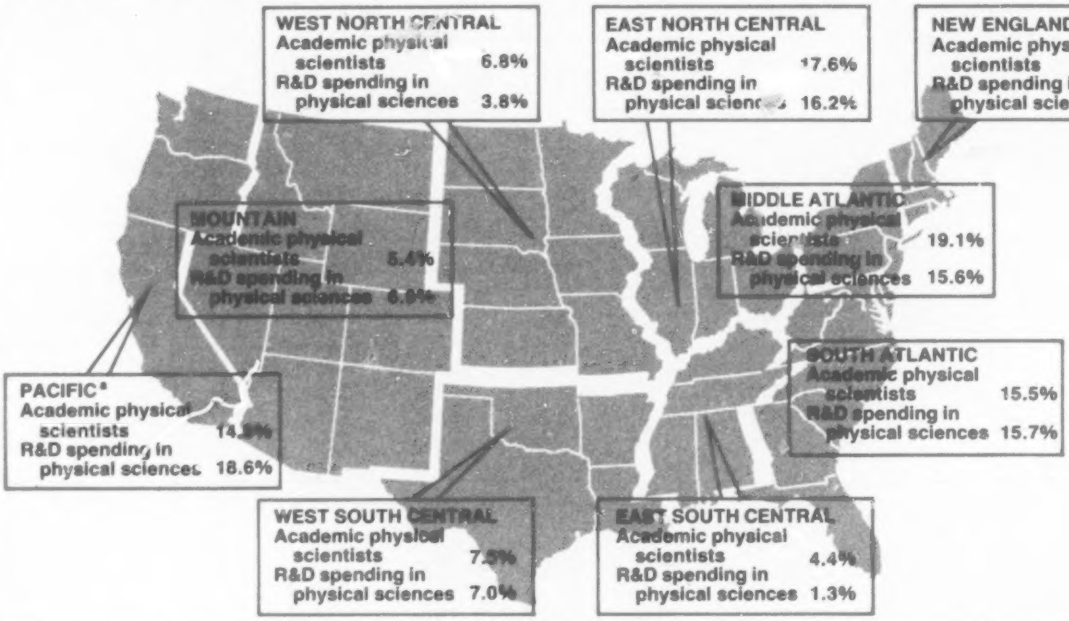
a In January. **Note:** Data not available for 1979. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: About 60% of total spent by top 50 schools

$ Thousands	Total spending 1981	1980	1979	1978	Federally financed spending 1981	1980	1979	1978
1 Massachusetts Inst. of Technology	$ 8,222	$ 6,764	$ 5,324	$ 6,242	$ 7,572	$ 6,311	$ 5,021	$ 5,837
2 California Inst. of Technology	6,901	6,328	5,297	4,108	6,196[a]	5,630	4,813	3,712
3 U of California, Berkeley	6,553	6,022	3,717	3,046	6,008	5,601	3,485	2,758
4 Harvard U	6,123[a]	4,797[a]	4,283[a]	3,905[a]	4,637	3,631	3,241	3,396
5 Stanford U	5,564	4,788	4,159	3,549[a]	5,337	4,609	3,775	3,266
6 U of Illinois, Urbana	5,239	4,261	3,963	3,211	3,847	3,424	2,696	2,426
7 U of Texas, Austin	4,779	3,970	3,373	3,057	3,017	2,564	2,282	1,931
8 Cornell U	4,618	3,808	3,414	3,423	4,062	3,404	3,087	3,137
9 Purdue U	4,600	3,596	3,438	2,857	3,715	3,151	3,087	2,500
10 U of California, San Diego	4,430	4,425[a]	3,757[a]	3,611	3,933	4,375[a]	3,707[a]	3,293
Total, first 10 institutions	**57,029**	**48,759**	**40,725**	**37,009**	**48,324**	**42,700**	**35,194**	**32,256**
11 U of California, Los Angeles	4,420	4,159	3,573	3,236	4,127	4,017	3,379	3,052
12 U of Minnesota	4,260	2,642	2,162	1,803	3,494	2,143	1,624	1,415
13 U of Chicago	4,139[a]	3,958[a]	3,418[a]	3,113[a]	3,719	3,558	3,039	2,803
14 U of Wisconsin, Madison	4,122	3,976	3,346	5,149	3,134	2,944	2,353	2,933
15 Texas A&M U	4,069	4,097	3,715	3,261	2,793	2,945	2,361	2,243
16 Johns Hopkins U	4,066	4,652	4,064[a]	1,160	3,881	4,444	3,968[a]	1,084
17 U of Colorado	4,047	3,332	2,544	899	3,146	2,605	1,942	688
18 U of Notre Dame	3,855	3,457	[illegible]	2,475	3,738	3,328	2,618	2,389
19 Georgia Inst. of Technology	3,660	3,655	3,577	2,784	2,030	2,118	2,110	1,551
20 Indiana U	3,637	3,147	2,644	2,236	3,042	2,635	2,306	1,959
Total, first 20 institutions	**97,304**	**85,834**	**72,514**	**63,125**	**81,428**	**73,437**	**60,894**	**52,373**
21 Columbia U, main division	3,564	4,437	3,531	3,321	3,471	4,054	3,202	2,854
22 Pennsylvania State U	3,413	2,973	2,303	1,904	2,773	2,527	1,989	1,590
23 U of Pennsylvania	3,386	3,688	2,211	1,761	3,073	3,143	1,840	1,356
24 U of Massachusetts, Amherst	3,230	1,689	2,621	2,038	2,067	1,632	1,921	1,633
25 Ohio State U	3,227	2,654	2,039	1,740	2,679	2,144	1,743	1,493
26 U of Maryland, College Park	3,109	2,766	1,907	1,975	2,418	2,292	1,628	1,690
27 U of Utah	3,076	2,611	2,290	2,754	2,720	2,373	1,949	1,909
28 Florida State U	3,012	2,791	2,478	1,490[b]	1,463	1,313	1,160	777[b]
29 Northwestern U	2,995	2,367	1,851	1,854	2,813	2,221	1,671	1,681
30 U of Rochester	2,966	2,089	2,536	2,100	2,553	1,667	2,058	1,695
Total, first 30 institutions	**129,282**	**114,299**	**96,281**	**84,062**	**107,458**	**96,803**	**80,053**	**69,051**
31 Yale U	2,781	2,023	2,107	1,444	2,609[a]	1,886	1,750	1,379
32 State U of New York, Stony Brook	2,691	1,966	1,801	1,637	2,080	1,632	1,554	1,281
33 Princeton U	2,513	2,065	2,242	1,660	2,142	[illegible]	1,621	1,271
34 Colorado State U	2,385	1,973	1,774	1,398	2,079	1,717	1,579	1,193
35 U of Southern California	2,345	2,313	2,181	1,676	1,639	1,773	1,731	1,381
36 U of Florida	2,302	2,283[a]	1,968	1,265	1,156	1,214[a]	1,339	1,077
37 Rensselaer Polytechnic Inst.	2,286	1,551	968	900	1,310[a]	962	680[a]	660
38 Wayne State U	2,261	2,163	2,022	2,740	1,636	1,640	1,555	1,926
39 Syracuse U	2,259	764	691[a]	382	551	396	327	295
40 Carnegie-Mellon U	2,225	2,075	1,957	3,828	1,768	1,515	1,408	1,542
Total, first 40 institutions	**153,330**	**133,475**	**113,992**	**100,992**	**124,428**	**111,184**	**93,592**	**81,056**
41 State U of New York, Buffalo	2,203	1,665	1,143	1,008	1,626	1,163	817	785
42 Michigan State U	2,178	1,638	1,491	1,262	1,541	1,157	[illegible]	878
43 U of Nebraska, Lincoln	2,175	2,289	1,745	1,040	1,757	1,909	983	769
44 Arizona State U	2,153	1,449	1,076	1,011	1,958	1,365	805	964
45 Case Western Reserve U	2,139	1,938	1,413	1,190	1,732	1,617	1,145	940
46 U of Pittsburgh	2,039	1,641	1,728	1,709	1,581	1,366	1,416	1,201
47 U of Michigan	2,016	2,064	1,406	1,171	1,591	1,775	1,229	982
48 U of North Carolina, Chapel Hill	2,016	1,789	1,685	1,413	1,936	1,752	1,666	1,398
49 Washington State U	1,920	1,043	785	751	946	804	673	651
50 U of California, Irvine	1,915	1,398	1,277	1,435	1,821	1,344	1,243	1,372
TOTAL, FIRST 50 INSTITUTIONS	**$174,084**	**$150,389**	**$127,741**	**$112,982**	**$140,917**	**$125,436**	**$104,614**	**$ 90,996**
NATIONAL TOTAL	**$283,883**	**$243,798**	**$205,830**	**$183,131**	**$215,890**	**$189,228**	**$156,516**	**$138,001**

a Estimated. b Imputed. **Note:** Data for institutional fiscal years. **Source:** National Science Foundation

Biggest concentration of academic physical scientists is in the Mid-Atlantic, but West Coast schools spend more on R&D in the physical sciences


WEST NORTH CENTRAL
Academic physical scientists 6.8%
R&D spending in physical sciences 3.8%
EAST NORTH CENTRAL
Academic physical scientists 17.6%
R&D spending in physical sciences 16.2%
NEW ENGLAND
Academic physical scientists 8.8%
R&D spending in physical sciences 14.9%
MOUNTAIN
Academic physical scientists 5.4%
R&D spending in physical sciences 6.9%
MIDDLE ATLANTIC
Academic physical scientists 19.1%
R&D spending in physical sciences 15.6%
PACIFIC[a]
Academic physical scientists 14.9%
R&D spending in physical sciences 18.6%
SOUTH ATLANTIC
Academic physical scientists 15.5%
R&D spending in physical sciences 15.7%
WEST SOUTH CENTRAL
Academic physical scientists 7.5%
R&D spending in physical sciences 7.0%
EAST SOUTH CENTRAL
Academic physical scientists 4.4%
R&D spending in physical sciences 1.3%

Key to map: Using the Middle Atlantic states as an example, 19.1% of all physical scientists employed at U.S. universities and colleges are located in this geographical area and 15.6% of all R&D expenditures in the physical sciences by universities and colleges are in this area. a Includes Alaska and Hawaii. **Note:** Data are based on 33,966 physical scientists employed at universities and colleges in the U.S. as of January 1982, and R&D expenditures of $762.9 million in the physical sciences during these institutions' 1981 fiscal year. Data exclude universities and colleges in outlying areas. **Source:** National Science Foundation

CHEMICAL DEGREES: Engineering degrees up 2%; those in chemistry down 1% in 1981

Academic year	Degrees awarded in chemistry[a]			Degrees awarded in chemical engineering		
	Bachelors	Masters	Ph.D.s	Bachelors	Masters	Ph.D.s
1965–66	9,735	1839	1571	2848	994	354
1966–67	9,872	1831	1744	2869	949	305
1967–68	10,847	2014	1757	3211	1156	367
1968–69	11,807	2070	1941	3557	1136	409
1969–70	11,617	2146	2208	3720	1045	438
1970–71	11,183	2284	2160	3615	1100	406
1971–72	10,721	2259	1971	3663	1154	394
1972–73	10,226	2230	1882	3636	1051	397
1973–74	10,525	2138	1828	3454	1045	400
1974–75	10,649	2006	1824	3142	990	346
1975–76	11,107	1796	1623	3203	1031	308
1976–77	11,322	1775	1571	3581	1086	291
1977–78	11,474	1892	1525	4615	1237	259
1978–79	11,643	1765	1518	5655	1149	304
1979–80	11,446	1733	1551	6383	1271	284
1980–81	11,347	1654	1622	6527	1267	300

a Does not include biochemistry and geochemistry. **Source:** Department of Education's National Center for Education Statistics

GRADUATE SCIENCE STUDENTS: Enrollment in chemical sciences grows moderately

Thousands	1981	1980	1979	1978	1977	1976	1975
TOTAL							
Physical sciences	**25.8**	**25.4**	**24.9**	**24.7**	**24.9**	**24.8**	**24.6**
Chemistry	15.3	15.1	14.9	14.8	14.6	14.4	14.1
Physics	9.9	9.6	9.3	9.2	9.5	9.7	9.7
Engineering	**77.0**	**72.3**	**68.9**	**65.8**	**65.8**	**64.2**	**64.6**
Chemical	6.5	6.1	5.6	5.3	5.2	5.2	5.1
Metallurgical and materials	3.0	2.8	2.6	2.5	2.5	2.3	2.3
Petroleum	0.5	0.5	0.4	0.4	0.4	0.4	0.3
Biological sciences	**41.3**	**42.1**	**42.1**	**42.7**	**42.7**	**41.6**	**40.6**
Biochemistry	3.9	3.8	3.8	3.9	3.8	3.7	3.7
Other sciences[a]	**196.1**	**193.9**	**184.7**	**176.6**	**173.1**	**167.5**	**163.9**
TOTAL	**340.2**	**333.7**	**320.5**	**309.8**	**306.5**	**298.1**	**293.6**
FULL TIME ONLY							
Physical sciences	**22.6**	**22.3**	**21.8**	**21.5**	**21.8**	**21.6**	**21.3**
Chemistry	13.2	13.1	12.8	12.7	12.6	12.4	12.0
Physics	8.8	8.5	8.3	8.2	8.5	8.5	8.5
Engineering	**45.4**	**42.5**	**39.8**	**37.4**	**37.1**	**36.5**	**37.1**
Chemical	5.1	4.6	4.3	4.0	4.0	3.8	3.6
Metallurgical and materials	2.4	2.2	2.1	1.9	1.9	1.8	1.8
Petroleum	0.4	0.4	0.3	0.3	0.3	0.3	0.2
Biological sciences	**34.9**	**35.3**	**35.3**	**35.5**	**35.8**	**35.2**	**34.5**
Biochemistry	3.6	3.6	3.5	3.6	3.5	3.4	3.4
Other sciences[a]	**131.6**	**130.6**	**126.5**	**122.1**	**122.8**	**120.7**	**117.3**
TOTAL	**234.5**	**230.6**	**223.4**	**216.6**	**217.4**	**214.1**	**210.3**

a Includes environmental, mathematical, computer, health, agricultural, and social sciences and psychology. **Note:** Data for Ph.D-granting institutions only. **Source:** National Science Foundation

New chemical tariff system takes shape Page 12

AUGUST 1, 1983

CHEMICAL & ENGINEERING NEWS

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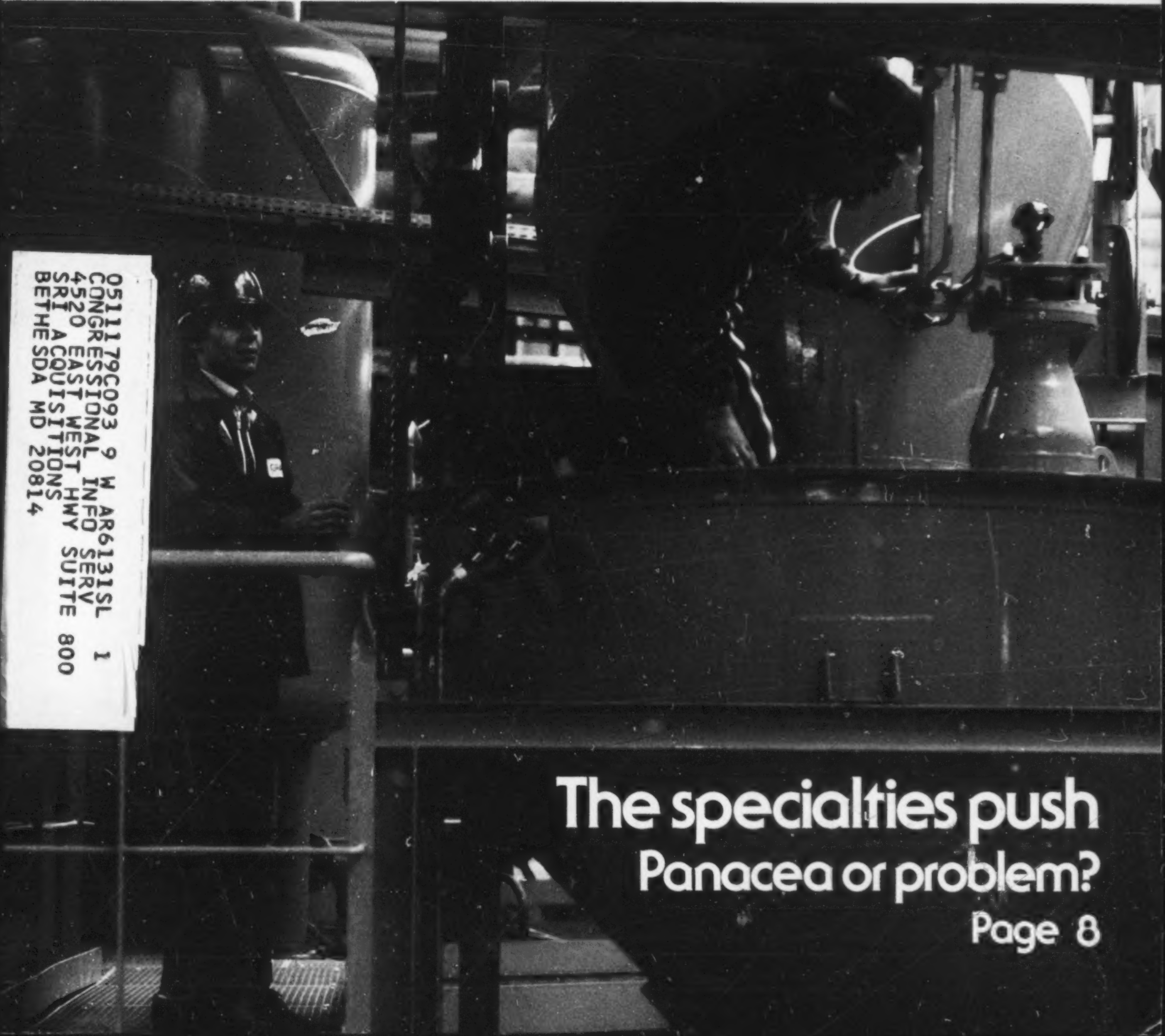

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The specialties push

Panacea or problem?

Page 8

Cover: Specialty producer W. R. Grace's
battery separator plant at Sélestat, France

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News of the Week

- **Recommendations for research to solve world food crisis come from CHEMRAWN II deliberations. Page 4**
- **U.K. biotech firm will apply gene engineering to agriculture. Page 5**
- **Top management changes made at Monsanto and Celanese. Page 5**
- **GAF reverses its decision to self-liquidate. Page 6**
- **Sohio, chemical research group fund academic research. Page 6**

Business

Plastics use in beverage bottles predicted to soar, at expense of glass and paper; metal expected to hold its own. **Page 11**

International

New U.S. coding system for trade commodities conforms with international tariff nomenclature; new alumina plant at Aughinish Island, Ireland, will start up in September. **Page 12**

Government

Panel assessing government research labs recommends assigning well-defined missions; Office of Toxic Substances focuses on tightening regulation of chemicals. **Page 16**

Science

Penning ionization electron spectroscopy used to study electron densities of the outermost molecular orbitals. **Page 20**

Technology

Phillips Petroleum process to make single-cell protein boasts ultrahigh cell density, no need for centrifugation. **Page 21**

New deck coating for aircraft carriers lasts longer and is less likely to damage airplane engines; large-scale melt facility at Sandia labs will study dangers of nuclear reactor fuel melts. **Page 22**

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Impact of new technology on employment, economics, cultural and social systems discussed at NAE symposium. **Page 23**

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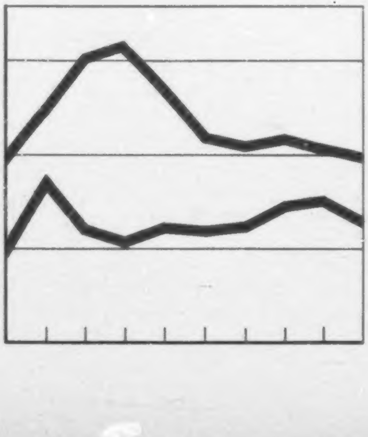


Cover Story

Lure of the high-profit-potential specialties industry is strong for commodity chemical makers, but abundance of management problems adds to risks. Page 8

Specialty Chemicals Push Raises New Management Problems

Commodity chemical firms trying to get higher profits by entering specialties should know they will have to make major management changes

William J. Storck, C&EN New York

A rush into specialties is the key part of a lot of U.S. chemical companies' strategy for reviving profits in the 1980s. The movement actually began in the 1970s, but the attention paid to specialties and their higher potential profitability really has gained momentum in the past few recessionary years.

The list of existing and potential producers includes not only traditional specialty chemical companies such as Lubrizol and Petrolite but also commodity chemical producers like Du Pont and Dow Chemical and companies like Uniroyal and Beatrice Foods whose main business has never been chemicals. In perhaps the best known case, Dow has posted a goal of half its earnings in specialties by 1990.

Questions remain, though, whether the specialties campaign is going to be all that good for the chemical industry, and, indeed, whether the nonspecialty-oriented companies can even pull it off.

Charles H. Kline, president and director of Charles H. Kline & Co., a Fairfield, N.J.-based consulting firm, defines specialty chemicals as chemicals sold primarily on a performance basis—the ability to do a very specific job. Most producers of specialty chemicals regard them as products for which technical service to customers is at least as important as the product itself. In other words, the producing company must spend time and effort with the customer discovering exact needs and fitting the product to those needs, or adapting the customer's process so that it can use a particular product.

Primarily two concerns are voiced about commodity companies' increasing emphasis on specialties. The first is a potential damaging effect on existing specialty companies. The second is commodity companies' actual ability to do what they say they want to do.

Vincent L. Gregory Jr., chairman and chief executive officer at Rohm & Haas, which has a large specialty chemical operation, says that there is no question but that the specialties push poses a problem for traditional specialty producers. "But, it does not terrify us," he says. Although newcomer companies, according to Gregory, are looking at the Rohm & Haas type of arrangement—with a combination of specialty products atop a commodities base, rather than the purely specialty route of Nalco Chemical, Lubrizol, or Loctite—he believes that if an existing specialty company can protect its niches, it can maintain its specialty areas. In other words, since specialty chemicals generally are sold for very specific uses with special marketing needs, specialty companies likely will be able to maintain their lead in the areas they already dominate.

This also means that commodity companies may find that they have a hard time developing their own specialty businesses. One industry executive says the specialty companies have so much experience behind them, that product development is much easier than for a company just entering the field.

Since a standing start in specialties is so difficult, acquisitions may be the best way for commodity companies to get into the specialty field, many sources say. Unfortunately, acquisitions of specialty companies can be a

Pesticides market offers huge barriers to entry

Pesticides have long been thought of as one of the glamor products in the specialty chemical arena. A lot of companies—most notably Monsanto with most of its profit in this area—have made a lot of money in pesticides. They are truly high-value-added products. However, much of the high earnings seems to come from a combination of innovation, good marketing skill, and a lot of luck.

First, there is the process of developing a commercial product. It has been estimated that only about one of every 12,000 compounds developed in agricultural chemical research makes it to the marketplace. Most of the other compounds are weeded out by potential production problems, lack of government approval, or the fact that they just plain don't work. Second, the average wait for government approval is up to seven years, and during that time, the firm must continue to spend money on safety and efficacy testing. Finally, the producer must get its product accepted by growers, a sometimes difficult thing to do when the grower's yearly income is tied up in just one planting.

After the company spends all of this time and money on product development, safety testing, and advertising, it has at most about 10 years to recoup its investment. After that the product goes off patent and generic producers move in with much lower-cost products and take away a large part of the original producer's sales.

Specialties trend will have weighty financial impact

One of the most important effects of the chemical industry's emphasis on specialty products for the 1980s will be purely financial. Of course, industry leaders hope that specialties will pick up profits. But there's much more to it than that. From a financial point of view, specialties are quite different from the industry's traditional commodity businesses. Money flows alter radically as companies change the emphasis from products like ethylene and chlorine to products such as herbicides, engineering plastics, and electronic materials.

Besides the obvious boost in value added and, hopefully, a resulting boost in profits, specialties tend to rearrange company finances in other ways. Most important, specialties are usually less capital-intensive. That is, they take less investment money for new plants.

On the other hand, specialties are likely to increase the industry's need for all kinds of technical backup for products, from basic research through development to technical service. In other words, R&D budgets will go up sharply, adding to companies' current costs. This already has happened in the chemical industry; C&EN surveys show that R&D budgets at leading companies have more than doubled in the past six years (C&EN, July 25, page 52).

Some idea of specific dimensions in these financial shifts comes out in an extreme comparison—between commodity-heavy basic chemical companies and one of the ultimate specialty areas, the drug industry. Admittedly, chemical firms may never become so specialty-oriented as ethical drug firms. But the contrast tells something about the direction of chemical companies' money management.

Both cash sources and uses are very different between the two groups. A survey of five commodity-rich chemical firms (Celanese, Dow Chemical, Hercules, Monsanto, and Union Carbide) and five pharmaceutical companies (Eli Lilly, Pfizer, G. D. Searle, Squibb, and Upjohn) shows first that cash intake after taxes and ordinary running expenses differs notably in both good years and bad. Of the three leading sources of companies' cash—earnings, depreciation, and new long-term debt—earnings are overwhelmingly important for the drug companies—77% of the total for these three sources in recessionary 1982 and 70% in booming 1979. Drug companies get relatively little cash from depreciation—21% of the total in 1982 and 16% in 1979—and next to nothing from debt—2% in 1982 and 14% in 1979.

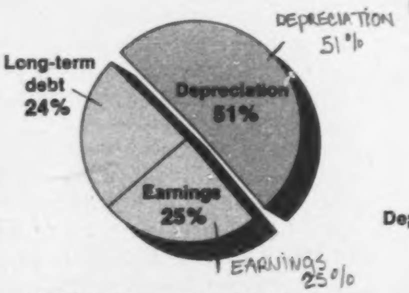
In sharp contrast, basic chemical companies get much less of their main cash elements from earnings—25% in a very poor 1982 and 43% in robust 1979. However, these capital-laden firms enjoy large depreciation—51% of total cash in this survey in 1982 and 40% in 1979. And they take down much more long-term debt—24% of the total in 1982 and 17% in 1979.

In cash use, chemical companies put relatively more into new plant and equipment than do drug companies even in depressed years. Of the three main uses of company cash—capital spending, dividends, and long-term debt payments—capital spending accounted for 60% of the total for chemical companies in 1982 and 73% in 1979. For drug companies, the corresponding figures were 59% and 53%.

In smaller cash outlets, the biggest difference is in dividends, which made up 34% of drug companies' use of these three cash elements in 1982 and 39% in 1979. For chemical companies, dividends took just 16% of the total in both years. In the category of debt reduction, the numbers are reversed, as might be expected. Debt payment took fully 24% of chemical companies' total for these cash uses in 1982 and 11% in 1979. For drug companies, much smaller financing needs resulted in just 7% of these cash uses for debt payment in 1982 and 8% in 1979.

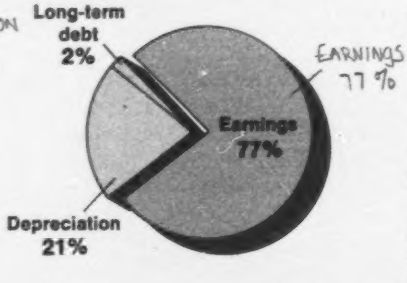
William Fallwell, Washington

Commodity makers lean heavily on depreciation . . .



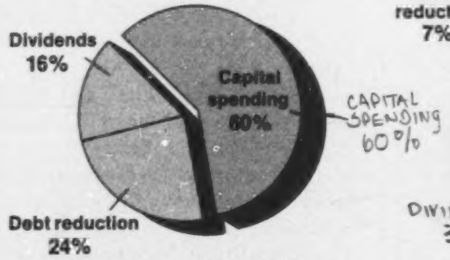
1982 cash source = $4.1 billion

. . . while specialty firms still have rich earnings



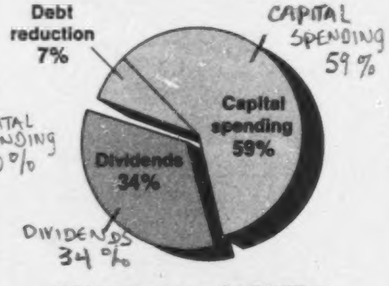
1982 cash source = $1.5 billion

Commodities demand big capital spending, debt . . .



1982 cash use = $5.2 billion

. . . while specialties firms can afford higher dividend rate



1982 cash use = $1.5 billion

Note: Data are for five commodity chemical producers—Celanese, Dow Chemical, Hercules, Monsanto, and Union Carbide—and for five specialty drug producers—Eli Lilly, Pfizer, Searle, Squibb, and Upjohn.

very expensive route because of Wall Street's high premium on their stock prices.

One other problem that some see for the specialty companies if the commodity producers begin to move in is pricing. Many specialty producers worry that, especially in times of economic slowdown, traditional commodity companies may start to cut the price of specialties to maintain markets. "I would much rather see Dow be the best commodity chemical producer in the world, perhaps driving the others out of business, than see it get deeper into specialties," says one chemical executive. He is worried that companies such as Dow and others that have traditionally sold on the basis of price, will turn high-value-added specialties into mini-commodities.

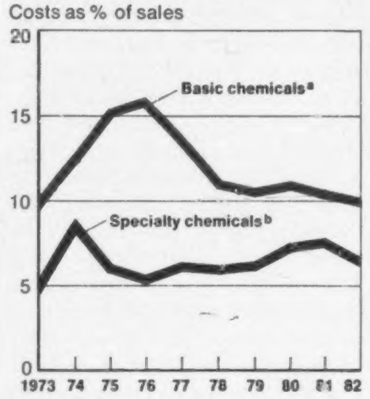
Others are not so sure. In fairness to Dow, Robert Todd, vice president of chemical services for Citibank in New York City, says that of the large chemical companies Dow probably can handle specialties as well as, if not better than, most others. "Dow has always had the attitude that if the customer wants new products and expanded plants, he is going to have to pay for them."

However, everybody points out that when the oil companies went into specialty chemicals, they did sell on the basis of price. This got them into real trouble, according to one analyst.

It's experiences like these that have some executives concerned. Rohm & Haas' Gregory says, "When commodity companies decide to go into specialties they are going to have problems. It's a completely different psychology—a different way of doing business. They can't go in and buy a specialty chemical outfit and think that they are going to run it on price. It just won't work."

Commodity companies just don't seem to realize the amount of service they will have to provide when they get into specialty chemicals, according to another industry executive. And they don't realize the extent of training of their own sales forces that is involved. If a company wants to get into specialties, he says, it will take a very large sales force that takes a very long time to train.

Lower capital costs make specialties attractive

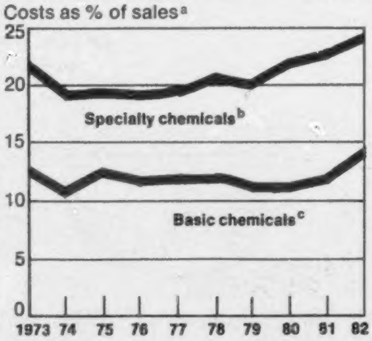


a Average for Dow Chemical, Union Carbide, Monsanto, Celanese, and Hercules. b Average for Lubrizol, Loctite, Nalco, Petrolite, and H. B. Fuller.

Larger sales forces plus high research and development spending seem to be the keys at successful specialty chemical firms. For instance, C&EN found that at five specialty chemical companies—Loctite, Lubrizol, Nalco Chemical, Petrolite, and H. B. Fuller—selling, administrative, and general expenses, plus R&D costs, averaged more than 24% of sales in 1982. Last year, at five predominantly basic chemical companies—Dow Chemical, Union Carbide, Monsanto, Celanese, and Hercules—these same costs totaled only 14% of sales. What this means is that specialty companies actually are providing a service, of which a chemical is only a part.

The biggest problem is that acquisitions of specialty chemical companies by commodity producers—the best way to go, according to many people in the industry—simply will not have a very big effect on the larger companies' earnings. The majority of acquisitions of specialty chemical firms take place when sales are at $20 million to $30 million or below. According to Citibank's Todd, if a specialty company can get past this acquisition sales threshold, then it may easily become too expensive to acquire because of the stock's high price-earnings ratio.

Selling, development costs higher for specialty makers



a Selling, general, and administrative plus R&D costs. b Average for Lubrizol, Loctite, Nalco, Petrolite, and H. B. Fuller. c Average for Dow Chemical, Union Carbide, Monsanto, Celanese, and Hercules.

Then, there is the problem of day-to-day operations. One specialty marketer says that in a commodity business, the producers are faced with essentially one question: whether or not to build a plant. In specialties, however, that is just the first step, and since capital costs generally are lower for specialties, a plant is perhaps not even the most important step. Once a producer decides to get into a specialty area, it must then make decisions on new products, R&D effort, staffing, and a host of other considerations.

The final problem for companies just getting into a specialty business, no matter what their previous orientation, is customer acceptance. Producers say that the high service content of their business leads in most cases to great customer loyalty. Just because a commodity producer comes along with a competitive product, even at a lower price, the customer may balk at switching.

The one part of the specialties push that has some people mildly excited is the application of specialty techniques to commodity chemicals. According to Todd, for example, there are great opportunities in plastics for some new specialty uses. In another instance, some industrial gas producers have set up specialty segments to market small amounts of large-volume gases in a specialty manner. One application is the marketing of very-high-purity nitrogen to the electronics industry. If specialty management begins to rub off on traditional commodity chemicals this way, then commodity producers' new fascination with specialties may be worthwhile even if the drive falls short of producers' fondest hopes. □

CHEMRAWN recommendations focus on world food supply
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Chemicals for electronics

One of the strongest growth markets
Page 7

Cover: Surface detail of one of the new 256K RAM superchips made by Western Electric at Allentown, Pa.

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News of the Week

- **U.S. and China sign bilateral trade agreement on import of Chinese textiles and apparel.** Page 4
- **Monoclonal antibody kit allows physician to identify quickly bacteria causing meningitis.** Page 4
- **Chemical industry productivity is gaining sharply in second-half 1983, reversing trend.** Page 5
- **House/Senate conferees decide to end U.S. moratorium on new chemical weapons.** Page 5

Business

Outlook for titanium dioxide is good; a strong market is ahead, and possibly even a tightening of supply in a year. **Page 12**

International

Japanese petrochemical companies see improvement in second-half 1983, with help from the U.S.'s economic recovery. **Page 14**

Relative decline in U.S. pharmaceutical firms' R&D is endangering the drug industry's competitive position worldwide. **Page 15**

Government

National Science Foundation's chemistry division gets a pat on the back from outside advisory committee reviewers. **Page 20**

Science

Research leading to new technologies for pest control, crop yield, and soil improvement to feed the world's growing population recommended by CHEMRAWN II and NAS groups. **Page 23**

Technology

Process to grow high-strength carbon fibers found serendipitously during experiments at General Motors research lab. **Page 27**

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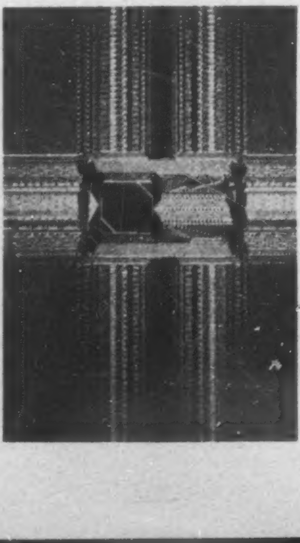


Cover Story

Chemicals for the high-flying electronics industry are enticing market, especially in resists for making new circuits. **Page 7**

Chemicals for Electronics: New Growth in Competitive Field

After low growth for three years, electronics chemicals are off and running again in high-technology race; biggest challenge is in photoresists

Stephen C. Stinson, C&EN New York

One of the premier targets for chemical companies in their drive for high-growth specialty markets in the 1980s is electronics. Activity is intense in both technology and marketing, with U.S. electronic chemical sales already totaling $2.4 billion. That figure could grow to $4.3 billion (deflated) in just five years.

The list of names in this field is notably diverse. The giants are there, including Airco, Air Products, Allied, Ashland Oil, Ciba-Geigy, Du Pont, Eastman Kodak, General Electric, W. R. Grace, Hercules, Monsanto, Union Carbide, and Westinghouse. But medium- and small-sized companies also are in abundance, such as J. T. Baker Chemical (part of Richardson-Vicks), Colonial Printing Ink (part of Millmaster Onyx), Dynachem (part of Morton Thiokol), Engelhard, Philip A. Hunt Chemical (majority owned by Olin), Shipley (minority owned by Rohm & Haas), UOP (part of Signal Cos.), and Wacker Siltronic.

Entry can be in many ways, since there are six major and seven minor product groups in electronic chemicals going to two major kinds of electronic applications (printed circuit boards and integrated circuits). But entry and survival aren't that easy; both take a heavy technical commitment, exemplified in such areas as the fast-changing photoresist market.

Now that the U.S. economic recovery apparently is fully under way, the electronics industry is rebounding from a three-year period of low growth, and with it, sales of chemicals and substrates needed to produce electronic components. This economic recovery comes at a time when suppliers and captive users of semiconductor integrated circuits must advance fabrication technology to make the next generation of higher-density chips for faster computers and other microprocessor-driven devices. Though development of the new fabrication technology will demand improvements in chemicals across the board, perhaps the greatest challenge for chemists will be to discover new polymers for use as resists (screening layers over substrates) to attain the higher resolution of features needed on semiconductor surfaces.

For the electronics industry, the recession began in 1980. The growth rate in sales and captive use of printed circuit boards in the U.S. fell to 4% from $2.7 billion in 1980 to $2.8 billion in 1981 after a 9% annual clip in the late 1970s. The rate slipped further in 1982, with printed circuit

Worldwide use of resists will forge ahead . . .

$ Millions (1980)	Sales and captive use 1980	Sales and captive use 1986	Average annual growth, %
UV screen inks	$ 17	$ 31	10%
Dry films	130	236	10
Liquids	79	210	18
TOTAL	$226	$477	13%

. . . with U.S. consuming the largest share . . .

Area			
U.S.	$125	$276	14%
Europe	59	106	10
Japan	42	95	15
TOTAL	$226	$477	13%

. . . and with microelectronics the fastest growing outlet

Use			
Printed circuit boards	$ 75	$144	12%
Microelectronics	41	121	20
Photochemical machining	9	11	4
TOTAL	$125	$276	14%

Source: R. M. Kossoff & Associates

Recovery will enlarge U.S. markets for electronic chemicals

$ Millions (1983)	Sales and captive use 1980	Sales and captive use 1983	Sales and captive use 1988	Average annual growth 1980–83	Average annual growth 1983–88
APPLICATION					
Semiconductors	$1200	$1500	$2900	7.8%	14.0%
Printed circuit boards	800	900	1400	4.0	9.0
TOTAL	$2000	$2400	$4300	6.3%	12.4%
PRODUCT CLASS					
Substrates	$900	$1100	2400	7.1	11.4
Plating chemicals	200	200		[a]	
Photoresists	100	100		[a]	
Packaging materials	300	400	1100	10.0	12.9
Acids & etchants	100	100		[a]	
Atmospheric gases	100	100		[a]	
Other[b]	300	400	800	10.0	15.0
TOTAL	$2000	$2400	$4300	6.3%	12.4%

[a] Rate of growth relatively small. [b] Includes specialty gases, cleaners, dopants, auxiliary materials, photoresist adjuncts, solvents, and solder masks. **Source:** C. H. Kline & Co.

Glossary of electronic chemical and processing terms

Chemical vapor deposition. Deposition of silicon, silicon nitride, or doped silicon dioxide glass layers onto silicon wafers by high-temperature decomposition of appropriate gaseous compounds in a chamber.

Dry film resist. Photoresist for printed circuit boards containing a photoactive resin system between a polyethylene lower layer film and a polyethylene terephthalate upper layer, useful for defining lines and spaces less than 15 mils wide.

Integrated circuit. System of thousands of interconnected microscopic transistorlike regions formed in upper layers of wafers of such semiconductors as silicon.

Metal-oxide semiconductor (MOS). Substance whose functioning depends on the greater electrical conductivity of a metal-like silicon compared with its relatively insulating oxide; fabrication is aided by greater mobility of dopant atoms in the metal than in the oxide.

Negative resist. Resist whose solubility in the developer is greater for light-unexposed than exposed areas, leading to formation of patterns by removal of unexposed zones.

Phototool. Glass or photographic film master of resist resin pattern to be produced on a silicon wafer or printed circuit board substrate; used by exposing the resist through the phototool in contact with the resist, separated from it by a minute distance, or by projection from a greater distance.

Positive resist. Resist whose solubility in the developer is greater in light-exposed than in unexposed areas, leading to formation of patterns by removal of exposed areas.

Printed circuit board. Reinforced plastic laminate board bearing linear patterns of electrically conducting metal whose features may range from 2 to 100 mils in width; such boards serve as mounting and interconnection for integrated circuits, transistors, diodes, capacitors, and coils that complete an electronic device.

Resist. Resin applied by screening or photochemical imaging and development, whose function is to provide a patterned protecting layer over areas of a substrate that are not to be affected by a subsequent etching or plating step.

Screen inks. Resists screened in a pattern on the surface of a printed circuit board, which then are cured in place by heat or ultraviolet light; patterns are formed on screens from photomasks using photoresists; useful for defining lines and spaces from about 15 to 100 mils wide.

Solder mask. Photoactive resin applied by liquid coating or dry film techniques, followed by photochemical imaging and development to leave small holes in the resin coat over the surface of a printed circuit board, to protect circuit elements from solder flow; not removed from board after use, solder mask resins are formulated for hydrolysis and fire resistance to protect the board during its life.

VLSI (very-large-scale integration). Current density level of functional features called gates incorporated onto the same size chip, amounting to more than 1000 gates per chip; contrasted with medium-scale integration (MSI) of 10 to 100 gates per chip or large-scale integration (LSI) of 100 to 1000 gates that were thought satisfactory a few years ago.

boards amounting to only $2.9 billion. At the outset of renewed health, values of printed circuit boards may grow from 15 to 20% in 1983 to $3.3 billion to $3.4 billion, and settle down to a steady 9% per year average increase over the next five years.

This faltering and resumption of high growth rates in electronics has been mirrored by sales of substrate materials and processing chemicals to the industry. Analyst Chem J. Listner of C. H. Kline & Co., Fairfield, N.J., estimates sales for printed circuit boards were $800 million in 1980, increasing only 4% annually to $900 million in 1983. But he predicts a 9% yearly increase thereafter to $1.4 billion in 1988 in constant dollars. Similarly in semiconductors, Listner says substrate and chemical sales for this use grew at 8% per year from $1.2 billion in 1980 to $1.5 billion in 1983. But this advance will accelerate to an average 14% per year to $2.9 billion in 1988, also in constant dollars.

Listner adds that technology as well as economic growth will be important for the electronic chemicals industry in coming years. Kline has introduced a new service to clients to track worldwide strategic developments in electronic chemicals on a continuing basis. Topics will include patterns of geographic shift in electronic component production and packaging, with emphasis on the importance of Southeast Asia; photolithographic trends in the U.S., Europe, and Japan; strategies of successful chemical suppliers; trends in processing components; and market surveys of selected, high-growth, specialty chemicals.

To chemists, new technology will bring challenges in terms of new high-density semiconductor integrated circuit chips. The new chips are exemplified by so-called 256K random-access memory (RAM) chips, which actually contain 262,144 bits of memory on the same size chip used to make 64K, 16K, and earlier RAM devices. IBM already makes such chips for captive use. Western Electric Co. expects to begin marketing these memories on the merchant market in the fall of this year.

Because speed of signal transmission dictates overall computer speed, electronics firms push to crowd more functions onto chips of the same size. RAM chips are important, because these are high-volume items on which chip makers will cut their new technological teeth. Later, success in 256K RAM chips would allow semiconductor fabricators to use the same very-large-scale integration (VLSI) technology for microprocessors and other integrated circuit devices.

But successful VLSI fabrication means creating features on silicon wafer surfaces to resolutions of 1 μm (1 millionth of a meter). In a chip-making context, resolution means ±10% with uniformity over the area of work. These fine resolutions begin to approach the 320 to 430 nm (1 billionth of a meter) wavelengths of ultraviolet light used in photolithographic processes today. Intense effort is under way to develop methods that use shorter wavelengths. These methods include deep UV (less than 300 nm), electron beam, and x-ray. Use of such methods will need not only automated machines and optics but also new photosensitive polymers as resists.

Indeed, the whole field of resists for all electronic devices is the subject of vigorous research and competition. Richard M. Kossoff, president of the consulting firm of R. M. Kossoff & Associates, New York, N.Y., estimates that the U.S. market alone in resists will grow from $125 million in 1980 to $276 million in 1986 at 14% average annual increases.

Kossoff says that resists have been highly profitable products in the past, though competitive price cuts on similar types from the growing number of producers have led to erosion of margins. He expects high profitability to continue for resist producers who develop resin systems for the new, high-resolution technologies. Apparent high profits, plus increased demand in the current electronic revolution, will lead to an increase in the number of firms serving the worldwide market from 46 in 1980 to 65 in the late 1980s. Some of the new corporate entrants in the U.S. resist market will be Japanese firms, Kossoff says, which will form partnerships with U.S. companies, license U.S. producers, or sell in this country on their own.

Types of resists differ according to the type of electronic devices to be made. Resists come in three main types. Photolithography of long-established printed circuit boards in consumer goods such as radios at resolution of lines and spaces 10 to 40 mils wide (1 mil = 1 thousandth of an inch or about 25 μm) uses one type, called screen inks. Resolutions from 15 down to 4 mils or less for computers and telecommunications devices often require a second type of resist called dry films, though two companies are trying to displace dry films with their photoimaged liquid coatings. Semiconductor integrated circuit chips demanding ultrafine resolution use the third type of resist, called photoimaged liquids.

Chip makers who are trying to make 256 RAM chips with their superfine 1-μm resolutions now depend on existing liquid resists that were satisfactory for the 2- to 2.5-μm resolutions of earlier, less dense chips. But these fabricators realize the need for new resists for the new, short-wavelength techniques, and some chip makers are taking the lead in developing these polymers.

In the first type of resist, screen inks, three companies dominate the U.S. market. Colonial Printing Ink Co., East Rutherford, N.J., subsidiary of Millmaster Onyx Corp.; Dynachem Corp., Tustin, Calif., subsidiary of Morton Thiokol; and W. R. Grace's Polyfibron division, Lexington, Mass., sell almost 90% of the total. Printed circuit board producers form the image of the resist ink pattern to be laid down by photoimaging on a stainless steel mesh or synthetic fabric screen. Ink flows through unblocked spaces in the screen onto the board, where it is cured. In the late 1960s Dynachem developed a UV-curable screen ink. Dynachem president Vern Ownbey estimates that 60% of screen inks today are UV-cured, though the rest are still heat-cured. UV curing is valued for greater speed and less space taken up by curing equipment.

In the second type of resist, films for fine-line circuitry resolution on printed circuit boards have a photoresist resin system sandwiched between a polyethylene and polyethylene terephthalate film. The U.S. market is divided about equally by Dynachem and Du Pont's Riston Products division, Wilmington, Del., though Hercules' graphics systems division, Wilmington, has about 2%. Du Pont and Dynachem developed the product about the same time in the late 1960s, and Du Pont has licensed Dynachem on its patent for the idea of using the sandwich between films. Hercules has not taken a license and is the defendant in a suit by Du Pont.

Electronic chemicals comprise world of specialty products

The electronics industry consumes a rich variety of solid, liquid, and gaseous chemicals, all of which are much more costly than grades used in other industries because of elaborate purification to remove chemical impurities and filtration to exclude particulates. Processes begin with such substrates as single-crystal silicon wafers for integrated circuits and copper-clad reinforced plastic laminates for printed circuit boards. These need cleaners to prepare them for making devices.

Screening or photolithography of resist resins into patterns on substrates exposes some areas and protects others from chemical processes that follow. Photoresists need developers to form protective patterns; some resists require adhesion promoters in advance; and all resists must be removed with strippers after one fabricating step to open the way for the next.

Such atmospheric gases as oxygen form insulating silicon dioxide layers on silicon wafers. Nitrogen provides inert atmospheres or produces passivating silicon nitride layers on wafers close to the end of processing. Compounds of antimony, arsenic, boron, and phosphorus dope entire wafers or patterned regions into electron-rich or -deficient areas, creating microscopic transistors. Acids and etchants like ammonium bifluoride and hydrofluoric acid eat patterns into silicon dioxide layers; sulfuric acid and hydrogen peroxide strip off some resists. Vapors of silane derivatives react to form conducting polycrystalline silicon interconnections. Radio frequency generates plasmas from specialty gases like carbon tetrafluoride, sometimes with added oxygen, for dry etching of features on wafers or stripping of resists.

Electronics firms draw on all types of plating technology to connect devices to the outside world. Anodes and salts of aluminum, copper, gold, nickel, platinum, titanium, and tin-lead find use here, as well as associated chelating agents, activators, catalysts, and brighteners. On printed circuit boards, resistlike resins called solder masks limit flow of solder to desired areas, then remain laminated to the board as protective coating during its lifetime.

On completion of the printed circuit board or integrated circuit, ceramics, epoxies, silicones, and polyurethanes form protective coatings for finished devices.

Thirty U.S. firms are major chemical suppliers to electronics industry

	Substrates	Packaging	Photoresists and adjuncts	Plating chemicals	Gases	Process chemicals	Cleaners and other specialties	Dopants	Other[a]
Airco					X			X	
Air Products					X				
Alco Standard, Synthane Taylor division	X								
Allied	X		X	X		X		X	
Ashland Oil			X			X			
J. T. Baker Chemical[b]			X			X		X	
BBF, Polyclad Laminates division	X								
Adolph Coors		X							X
Du Pont	X		X			X	X		X
Engelhard				X					X
Fortin Laminating	X								
General Electric	X	X							
Philip A. Hunt[c]			X	X		X	X		
Kyocera[d]		X							X
MacDermid			X	X		X	X		X
Mica	X								
Monsanto	X								
Morton Thiokol		X	X	X			X	X	X
NGK Spark Plug		X							X
NVF	X								
Oak Industries	X								
Occidental Petroleum, Sel-Rex and Udylite divisions				X			X		X
Shin-Etsu Chemical	X								
Shipley			X	X		X	X		
Siltec	X	X							
Technic				X					
UOP, Norplex division[e]	X								
Union Carbide	X		X		X	X	X	X	X
Wacker Siltronic	X								
Westinghouse	X								

a Includes auxiliary chemicals and solder masks. b Subsidiary of Richardson-Vicks. c Owned 63.4% by Olin. d U.S. subsidiary of Kyoto Ceramic. e Part of Signal Cos. **Source:** C. H. Kline & Co.

Dry film users peel off the polyethylene film and laminate the bare resin surface to the board substrate. The resist resin is exposed by UV light with a photographic film master through the polyester film layer. On peeling off the polyester film, the resist pattern is developed, using organic solvent or alkaline aqueous-based developer. After the plating or etching operation with parts of the substrate protected by the resist, the resist is stripped off with organic or alkaline aqueous stripper.

Companies are reluctant to discuss dry film resist chemistry. The base resin could be methyl methacrylate copolymerized with methacrylic or itaconic acid to render it alkali-soluble. The base resin could be mixed with a monomer such as pentaerythritol triacrylate, and the whole system rendered photosensitive with an anthraquinone derivative. Exposure to UV light would cause polymerization of the monomer, enmeshing the base resin in a three-dimensional polymer network to resist dissolving by alkali. Thus the resist would be dissolved away only from unexposed areas.

Du Pont and Dynachem also have solder masks based on dry film technology. Solder masks are resists designed to produce a patterned protective cover with open areas at board holes and surrounding metal pad areas, to guide the flow of solder only to those areas. Solder masks are not stripped from boards after application of solder, but are formulated with resins and additives to give flame retardance and resistance to hydrolytic, mechanical, and heat damage to protect the board during its lifetime.

Carl S. Gates, director of Du Pont's Riston Products division, notes that exposure of dry film resists through polyester films sometimes causes image distortion. He says the company plans a new formulation that will eliminate the need for such films. Both Du Pont and Dynachem have introduced aqueous developers and strippers to eliminate needs for organic solvent recovery systems.

Gates says the company has been test marketing an integrated system that automatically cleans boards, peels film from resist, laminates resist to boards, and exposes circuit images onto resists, all without operator intervention. Du Pont will expand marketing of the system this year. Dynachem's Ownbey says that his firm will introduce an automated system that will take boards from cleaning through development of resist images early in 1984.

In the past two years, however, two companies have brought liquid resists and solder masks to market to compete with dry films for fine-line circuitry. Materials costs for the liquids are alleged to be one third of those for dry films, but suppliers will have to show that liquids are at least as easy to handle as dry films to compete successfully. Ownbey is skeptical about the future of liquids against dry films, but remarks that his company also has developed a liquid to enter the market, depending on how successful Ciba-Geigy and W. R. Grace are with theirs.

W. R. Grace's Polyfibron division is silent on the chemistry of its ma-

Twenty-two firms are major suppliers of photoresists for electronics production

Company	UV screen inks	Liquids Positive	Liquids Negative	Dry films Positive	Dry films Negative	Dry films Solder masks
Allied		X				
AZ Photoresist Products[a]		X				
J. T. Baker Chemical[b]		X	X			
Ciba-Geigy			X			
Colonial Printing Ink[c]	X					
Dynachem[d]	X	X	X		X	X
Du Pont					X	X
Eastman Kodak		X	X			
EM Chemicals			X			
Erthone[e]	X					
W. R. Grace	X		X			
Hercules					X	
Philip A. Hunt[f]		X	X			
KTI[g]		X	X			
London Chemical[g]	X					
MacDermid	X	X				
Mead		X	X			
M&T Chemicals	X					
3M	X			X		
Norland Products			X			
Shipley[h]	X	X				
Wornow	X					

a Division of American Hoechst. b Subsidiary of Richardson-Vicks. c Subsidiary of Millmaster Onyx. d Subsidiary of Morton Thiokol. e Subsidiary of Asarco. f Owned 63.4% by Olin. g Subsidiary of Union Carbide. h Owned 30% by Rohm & Haas. **Source:** R. M. Kossoff & Associates

terials, but those of Ciba-Geigy's plastics and additives division, Hawthorne, N.Y., are based on photosensitive, heat-cured epoxies.

Gordon Buchi, who manages Ciba-Geigy's liquid resist business, says that base resin is made by condensation of epichlorohydrin, bisphenol A, and *p,p'*-bis(hydroxystyryl) ketone. The company's solder mask resin also contains copolymerized tetrabromobisphenol A as fire retardant. A cascading sheet of liquid coats cleaned, preheated boards passing under it. After drying of the resist film, it is exposed through a photomask. UV light causes cross-linking by [2+2] photocycloaddition reactions among unsaturated ketone units. Cyclohexanone dissolves away unexposed areas to develop the image. At this point, faulty boards can be stripped for reuse with 2-methoxy- or 2-ethoxyethanol or *N*-methylpyrrolidone. Otherwise, the board is heated to 275 °F for a final cure with a latent amidine hardener in the formulation. Thus, in contrast with most resists, the Ciba-Geigy material stays with the board.

Buchi explains that such a resist has the advantage of providing an epoxy coat that is compatible with epoxy laminations to follow in making boards. It also avoids stripping as an extra step, as well as treatment of

High thermal stability, sensitivity will be keys to success for electron beam resist candidates

POSITIVE RESISTS	Sensitivity[a]	Glass transition temp., °C
Methacrylates		
Polymethyl methacrylate	100	104
Polybutyl methacrylate	0.4	19
Polyphenyl methacrylate	150	110
Halogenated methacrylates		
Polytetrafluoropropyl dimethylmethacrylate	5	93
Polyhexafluorobutyl methacrylate	0.4	50
Polytetrafluoropropyl methacrylate-co-glycidyl methacrylate	0.4	65
Polytrifluoroethyl α-chloroacrylate	2.5	133
Polytrichloromethyl methacrylate	3.0	138
Cross-linked methacrylates		
Polymethyl methacrylate-co-methacrylic acid	20	150
Polymethyl methacrylate-co-methacrylic acid-co-methacryloyl chloride	20	140
Polymethyl methacrylate-co-*tert*-butyl methacrylate	1.6	131
Polyphenyl methacrylate-co-methacrylic acid	10	142
Polyolefin sulfones		
Poly(1-butene sulfone)	1.0	—
Poly(2-methyl-1-pentene sulfone)	4.0	—

NEGATIVE RESISTS	Reactivity[b]	Glass transition temp., °C
Epoxy and vinyl polymers		
Polyglycidyl methacrylate	0.028	78
Polyglycidyl methacrylate-co-ethyl acrylate	0.023	10
Polychlorohydroxypropyl methacrylate-co-dimethyl maleate	0.026	—
Diallyl phthalate	0.036	160
Vinyl-containing polydimethylsiloxane	0.2[a]	—
Halogenated aromatics		
Polystyrene	5.5	85
Poly(*p*-chlorostyrene)	0.28	122
Chloromethylated polystyrene	0.12	110
Iodinated polystyrene	0.42	156
Chloromethylated poly(α-methylstyrene)	0.23	170
Chloromethylated polynaphthyl methacrylate	0.28	113
Polyvinylnaphthalene-co-vinylbenzyl chloride	0.41	—
Polyvinylbenzyl chloride-co-glycidyl methacrylate	0.67	77
Polystyrene-containing tetrathiofulvalene units	6[a]	—

a Microcuries per sq cm. b Product of weight-average molecular weight and gel point radiation dose; sensitivities of negative electron beam resists are proportional to weight-average molecular weights. **Source:** Nippon Telegraph & Telephone Public Corp.

boards with possibly harsh organic solvent strippers.

Gerald Teplitzky, who is vice president for Grace's Letterflex business, says that the company sells automated machinery for cleaning, coating, exposing, and developing of boards. Ciba-Geigy has such a system for its liquid solder mask, with a manual step for exposure in the middle. The company sells only coating and developing units for its liquid resist.

Whereas photoimaged liquid, dry film, and screen ink resists for printed circuit boards are all of the negative type, both positive and negative liquid resists, the third overall type, find use in making semiconductor integrated circuits, with increasing emphasis on positive types. Developing negative resists dissolves away unexposed areas; exposed areas are dissolved away in positive ones. Philip M. Papoojian, marketing manager for electronic chemicals at J. T. Baker Chemical Co., Phillipsburg, N.J., estimates that positive resists for integrated circuits have 40 to 45% of that market now growing at 25 to 30% per year. Negative resists still have 55 to 60% of the market, Papoojian says, but annual growth will only pace the electronics industry itself at 10 to 15%.

Among the many firms who sell liquid resists for integrated circuits, three primary producers (one selling to formulators) have almost 90% of the U.S. market: Eastman Kodak's graphic arts division, Rochester, N.Y., Philip A. Hunt Chemical, Palisades Park, N.J., and Shipley Co., Newton, Mass. Eastman sells resist materials to other suppliers, such as J. T. Baker, which formulate them for sale to integrated circuit producers. In efforts to get into the integrated circuit resist market, Rohm & Haas bought a 30% interest in Shipley for $38 million in February 1982, and Olin Corp. paid $90 million the following December to acquire Turner & Newall Industries' 63% interest in Philip A. Hunt.

Although specific integrated circuit resist compositions are secret, many negative types are based on polyisoprene or polybutadiene, and some positive ones contain phenolic resins. Photosensitive additives in negative resists initiate cross-linking of double bonds in the base resin, making these exposed areas insoluble in developers. Derivatives of 2-diazo-1,2-naphthoquinone, mixed in relatively large amounts into phenolic novolacs, serve as dissolution inhibitors in these positive resists. Photolysis causes rearrangement of diazo compounds to 1-indenecarboxylic acid derivatives. Developing in aqueous alkali leaches phenolic resin and indenecarboxylate from exposed areas, while relatively nonpolar, unphotolyzed diazo compounds retard dissolving from unexposed zones.

One advantage of negative resists for integrated circuit production is good resistance to etching. Their greatest weakness, which is causing many electronics firms to switch over to positive resists, is poor resolution. Unlike dissolving of sugar in water, in which the solvent plucks molecules from a crystal surface, organic solvent developers for resinous resists must swell the polymer to leach uncross-linked chains out of the mass. Swelling is four to five times the 1-μm thickness of resist films. Negative resists also are sensitive to oxygen and must be used under nitrogen or vacuum.

In addition to better resolution, positive resists have the advantage of being imaged by projection rather than contact with the phototool (resist pattern). But positive resists have their faults. They are more expensive, less sensitive, poorer in adherence to substrate, and less forgiving during development. Solubility differences between exposed and unexposed regions are less for positive resists, requiring more attention to development conditions. □

Key Chemicals

Titanium dioxide heads for prosperity in 1984

Much of the pure white color in the world comes from the chemical titanium dioxide. Few substances dominate their use as does this durable inorganic pigment. It has competitors, but none are very big.

Unfortunately, as a business titanium dioxide has not had nearly the distinction as its application. Like synthetic fibers, titanium dioxide has wandered through most of the past decade trying to regain heights of the early 1970s. But also like synthetic fibers, the pigment finally may have a shot at good times.

Titanium dioxide may be close to the end of a long transition period extending from poor market years in the mid- and late 1970s through a plant shakeout in the next few years to a new series of strong market years. Remaining capacity is much higher quality now, with most old pollution problems under control. Markets are rebounding, especially in housing, and could see basic long-term growth in plastics.

In fact, industry analysts are beginning to wonder if supply of the product could become tight. Consider: If a few more very old sulfate-process plants close, the U.S. might need even greater net imports of titanium dioxide than it has now to meet demand. So far, that's no problem. European producers are eager to send over material while their economies are still weak. But in a few more years, there might not be enough surplus product in Europe to export. Adding to the squeeze in the U.S. could be rising U.S. titanium dioxide exports. They're going up strongly this year, and marketing people think they'll continue to rise after 1983.

The leading U.S. use of titanium dioxide, hard-surface coatings such as house paint, might have only minimal long-term growth, say industry analysts. But the pigment's use is rising an estimated 7% a year in pigmentation of fabricated plastics such as building siding.

As yet, U.S. producers haven't reacted to such forecasts with plant expansion beyond small debottlenecking programs. A major new plant is very expensive because of complex processing and doesn't yet seem justified.

For the immediate market outlook, see the following page.

Bruce Greek, Houston

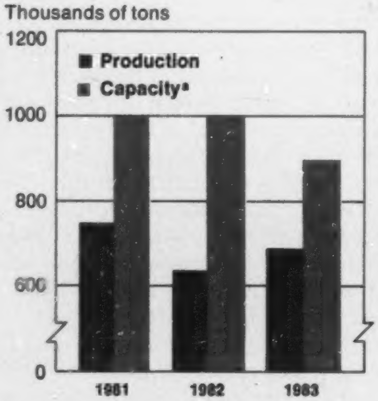
Key Chemicals

Titanium Dioxide

TiO_2

- ***Production recovering***
- ***Capacity down***
- ***Prices holding***

PRODUCTION/CAPACITY



[a] First quarter.

HOW MADE

Recovery from natural or synthetic ores using chlorine or sulfuric acid

MAJOR END USES (U.S.)

Hard-surface coatings 50%, paper coatings and fillers 25%, plastics and rubber fillers 15%, ceramics 5%

FOREIGN TRADE

Exports—rising to 80,000 tons in 1983, imports—rising to 175,000 tons in 1983

PRICES

Anatase form 69 to 70 cents per lb; rutile form 75 cents; discounting modest

COMMERCIAL VALUE

$950 million for production, 1983

The dominant white pigment, titanium dioxide, may have bright prospects ahead, but producers are having to take about one patient year to get there. For 1983, the product has to pick itself up from a worse than expected recession and move toward tighter capacity use. To date, the year has been just about what producers need to get on their new profits springboard.

Like most big-volume inorganics produced in the U.S., titanium dioxide usually doesn't move very fast. But production first nosedived 17% in 1982 and then about-faced for an expected 8% rebound in 1983. Meanwhile, one old plant was closed (NL Industries' at Sayreville, N.J.) and another was sold (Gulf + Western's at Ashtabula, Ohio, to SCM). Both imports and exports increased significantly. About the only thing that didn't change was the list price.

For the rest of 1983 and early 1984, the outlook for titanium dioxide continues upward as the economy improves. Most titanium dioxide used in the U.S. goes eventually into housing, automobiles, and paper—all consumer products now showing strong increases in demand. For 1983, titanium dioxide production probably will come close to 700,000 tons, well above 640,000 tons in 1982. However, 1983 production still will be below the recent high of 750,000 tons in 1981.

Plant capacity for titanium dioxide has dropped, levering up operating rates. With the closing of NL Industries' plant in late 1982, U.S. nameplate capacity declined to a bit more than 900,000 tons per year from the former 1 million tons. Even with some production lines not operating, a conservative estimate on 1983 production of 690,000 tons gives an operating rate of more than 75% of nameplate capacity. Effective capacity to make titanium dioxide reaches no more than 90% of nameplate, perhaps less, because of the complexity of the processing steps. So the effective operating rate is heading over 85%.

NL Industries' exit as a U.S. producer doesn't mean that its former production will all go to other U.S. producers. Imports have risen this year about 25% and might reach 175,000 tons, with an important part from NL's European operations.

Imports are somewhat offset by exports of titanium dioxide. In 1983, exports seem sure to reach 80,000 tons (up 14%) and possibly 90,000 tons (up 29%) if developing countries' economies recover and crude oil prices remain a reduced burden on these economies.

The surplus of imports over exports in 1983 could be as low as 65,000 tons if imports falter and exports boom, possibly pushing U.S. production higher than anticipated. If demand continues up as the recovery rolls along, supply of titanium dioxide might even start to tighten. Paint-maker SCM (Glidden) may have had this in mind with its plant purchase. Although the seasonal peak in paint demand usually would be over now for ordinary house painting, demand still is surprisingly strong for titanium dioxide. A wet spring seems to have pushed timing back, keeping up demand for trade (retail paint) sales deeper into summer than usual. Demand for paint in the fall also may be stronger than normal.

Housing and other "hard surface" coatings demand makes up about half the total market for titanium dioxide. The other half is dominated by paper coatings and fillers and by plastics and rubber colorants and fillers. The economic recovery boosts demand for higher-quality coated papers in many ways, for example in advertising pages and increased subscriptions in publications.

In another sphere, plastics are perhaps the best growth area for titanium dioxide demand even though they account for just 15% of the total. New developments such as plastic-film grocery bags to replace paper bags will help titanium dioxide, used in printing on the sacks.

Given another year for such new growth in plastics, coupled with recovery demand in paper and surface coatings, titanium dioxide could climb to well over 80% of nameplate capacity use, approaching the maximum U.S. plants can turn out. Since little new capacity is due, 1984 could move producers into the healthy profits stance they have waited so long to achieve. And companies might finally have to face a positive sort of challenge they haven't had in a long time—the need to consider an expensive major addition to capacity.

Drop in U.S. share of drug R&D endangers world position

Richard J. Seltzer, C&EN Washington

For decades, the U.S. pharmaceutical industry has been one of the most profitable and rapidly growing sectors of the U.S. economy. Together with other high-technology industries, it has played an important role in generating exports and trade surpluses. It continually has expanded its output, productivity, and employment, while holding price increases below the rate of inflation.

The pharmaceutical industry thus has maintained an image of immunity from the deteriorating international competitive position besetting other once robust U.S. industries such as autos, steel, textiles, machine tools, and consumer electronics.

However, warns a report just released by a National Academy of Engineering panel, "This image is apparently exaggerated, and probably false." The U.S. share of the world pharmaceutical market (measured in terms of sales and of introduction of new drugs) is still relatively stable—after a decline in the 1960s—despite growing competition from foreign producers; but the U.S. share of world pharmaceutical production and exports is only half what it was in the early 1960s. And most important, data compiled by the panel show the U.S. pharmaceutical industry suffering "a clear relative deterioration in the foundation of pharmaceutical competitive position—the research efforts necessary for discovery and introduction of new patented drugs."

The situation is thus one of relatively good health now, but there is a poor prognosis for the future. The panel, therefore, seeks in its report to answer three questions:

- What changes have occurred in the U.S.'s competitive position in the multinational pharmaceutical industry?
- Why have these changes occurred?
- What government policy steps can counteract the relative decline?

The study is entitled "The Competitive Status of the U.S. Pharmaceutical Industry: The Influences of Technology in Determining International Industrial Competitive Advantage." It is one in a series of seven reports on the international competitive status of specific U.S. industries prepared for NAE's Committee on Technology & International Economic & Trade Issues.

Chairman of the high-powered, 13-member pharmaceutical panel is Charles C. Edwards, president of Scripps Clinic and Research Foundation, and the rapporteur is Lacy G. Thomas, a professor at Columbia University's Graduate School of Business. Panel members include William N. Hubbard Jr., president of Upjohn; Lewis H. Sarett, a retired senior vice president of Merck; William M. Wardell, professor of pharmacology at University of Rochester Medical Center; Richard D. Wood, chairman and chief executive officer at Eli Lilly; and Alejandro Zaffaroni, chairman and chief executive officer of Alza Corp.

The study focuses on patented drugs and does not cover over-the-counter medicines or generic products. About 150 firms conduct research for and produce patented drugs in the U.S. Only 20 of them have significant U.S.-based multinational operations; about 20 more are U.S.-located operations of foreign-owned multinationals. The remaining firms have largely domestic sales, and some have only small research labs.

The panel points out that the importance of research and innovation for competition among major world pharmaceutical firms puts the industry in a select grouping of high-technology industries. Drug companies invest high proportions of sales and profits in R&D (more than 50% of profits, for example), and spend relatively high amounts on basic research (about 12% of U.S. pharmaceutical research is basic). There is also relatively little government financing of industrial R&D. These three trends rarely are present simultaneously in other industries.

To recoup their fast-rising expenditures for developing new drugs, major pharmaceutical firms have increasingly needed to sell their new products on a worldwide scale. Since most pharmaceutical innovations are not successful commercially, the firms depend on a handful of successful innovations. For example, in 1979, their three best-selling products provided two thirds or more of total U.S. pharmaceutical sales for each of four major drug firms. Thus, failure to produce a steady stream of new products—to replace those that lose market share to imitators or on which the 17-year-long patents expire—ultimately would be devastating to a pharmaceutical firm. Turnover is rapid. For instance, only four of the 30 top selling products in 1965 remained in the top 30 by 1980.

On the basis of their innovation, U.S. firms were predominant in world markets from 1950 to 1960, accounting for a large majority of research spending and new products,

U.S. share of world drug R&D down more than half

	1964		1973		1978	
	R&D spending ($ millions)	World share, %	R&D spending ($ millions)	World share, %	R&D spending ($ millions)	World share, %
U.S.	$282	60%	$640	34%	$1159	28%
West Germany	40	8	310	16	750	18
Switzerland	38	8	244	13	700[a]	17
Japan	27	6	236	13	641	15
France	28	6	166	9	328	8
U.K.	29	6	105	6	332	8
Italy	15	3	82	4	147	4
Sweden	9	2	33	2	72	1
Netherlands	9	2	26	1	72[a]	1

a Estimated. **Note:** Data are in current dollars and represent spending for both human and veterinary research. **Source:** Organization for Economic Cooperation & Development more than half world pharmaceutical production, and a third of international trade in medicinals. U.S. pre-eminence continued, although to a lesser degree, through the 1960s. However, since then the competitive advantage of U.S. firms "has been not only reduced, but apparently eliminated"—especially in the earliest phases of the discovery and development process. And this despite U.S. pre-eminence in basic biomedical research, and enormous U.S. government expenditures for biomedical research and health care.

Thus, the U.S. share in the world has been constant or declining since 1960 for each of six aspects of competitive industrial performance the panel considered: research effort, innovation, production, sales, market structure, and exports. The U.S. decline is not one in absolute terms, the panel emphasizes, but rather a result of slower growth rates than foreign competitors.

For instance, the U.S. share of world pharmaceutical R&D spending has fallen from 60% in 1964 to less than half this in 1982. Moreover, drug R&D spending (in constant value local currency) rose only 1.1% a year in the U.S. in the 1970s, while it was growing 13.1% in the U.K., 8.1% in Japan, and 7.9% in West Germany.

Meanwhile, the products of innovation—U.S.-owned new drugs entering clinical trials in the U.S.—have dropped steadily in number from a yearly average of 60 in the mid-1960s to about 25 a year in 1982. By contrast, foreign-owned drugs undergoing similar trials have remained almost constant at about 20 per year.

This decline in U.S. new-drug introduction does not reflect merely a decline in basic pharmaceutical innovation, the panel points out. The soaring expenses of premarket testing have forced firms to be much more selective of compounds to be tested clinically, and to be brought to market. These testing costs have risen faster in the U.S. than elsewhere.

Thus, in the U.S. the average cost per new drug (in constant 1980 dollars) has risen from about $6.5 million before 1962 to about $44.7 million in 1980 (excluding the cost of capital), primarily because of greater requirements for clinical and toxicology testing. The average R&D expenditure per drug, including capital cost, is estimated at $70 million. The average total time for clinical testing and drug marketing approval in the U.S. is in excess of eight years. Indeed, the panel notes, it now may take more than 15 years from initiation of basic research on a pharmacological problem to marketing of a new product.

Turning to another criterion for international competitiveness, the panel points out that the U.S. share of world pharmaceutical production has plummeted from 50% in 1962 to 38% in 1968 and 27% in 1978. U.S.-based production has been relatively stable, rising 5% a year in 1965–75. But West European and Japanese competitors raised production 15% a year. Meanwhile, U.S.-owned firms increased their production overseas much more rapidly than their domestic production, growing from $700 million overseas in 1963 to more than $6 billion in 1978. By 1978, overseas production accounted for 40% of the U.S. multinational total.

Two basic changes have occurred in the world pharmaceutical market structure during the past two decades—greater concentration of innovation among larger firms, and increasing internationalization of the industry. Both trends have important implications for U.S. competitiveness. First of all, not surprisingly, sharply rising costs of innovation are forcing smaller U.S. firms out of the game. This makes them increasingly

NAE probes relation of innovation to U.S. competitiveness

How can U.S. industry be made more competitive in world markets? A key factor is its ability to innovate new technology, notes chemist N. Bruce Hannay, foreign secretary of the National Academy of Engineering, who retired last year as vice president for research and patents at Bell Laboratories.

Hannay has set this issue as a major focus of his service since 1976 as NAE foreign secretary. He chairs a Committee on Technology & International Economic & Trade Issues, sponsored by NAE and by the National Research Council's Commission on Engineering & Technical Systems. The just-released report on the international competitive status of the U.S. pharmaceutical industry is but one link in the committee's ongoing study of relationships between technological innovation and productivity and the ability of U.S. industry to compete in international trade.

In the first phase of its work, the committee produced a report and four monographs. Published in 1978, the report, "Technology, Trade, and the U.S. Economy," indicates that the innovation process in the U.S. is not so vigorous as it used to be. The four monographs provide a more detailed examination of U.S. government policies and practices affecting technological innovation. They include: "The International Technology Transfer Process," "The Impact of Regulation on Industrial Innovation," "The Impact of Tax and Financial Regulatory Policies on Industrial Innovation," and "Antitrust, Uncertainty, and Technological Innovation." (All are available from the NAE foreign secretary's office.)

The second phase of the committee's work is a set of seven studies, each prepared by a panel with expertise on a specific industry. Published last year and earlier this year have been reports on the international competitive status of the auto industry, machine tools industry, and the fibers, textiles, and apparel industry (C&EN, May 9, page 5). Still to come after the pharmaceutical report are studies covering the electronics industry (slated for September), ferrous metals (November), and civilian aviation (January).

The objective of the seven studies is to identify global shifts in industrial technological capacity on a sector-by-sector basis; relate these shifts in international competitive advantage to technological and other factors; and assess prospects for further technological change and industrial development. The panel preparing each study also suggests a series of policy options for consideration by public and private policy makers. Besides experts serving on the panels, outside specialists, government officials, and Congressional staff members also are consulted.

dependent on licensing new products from foreign firms instead of developing new drugs themselves. It also makes them prime targets for takeover by foreign firms seeking entry to the U.S. market.

During the 1970s, European pharmaceutical firms established a broad multinational base in the U.S. market that in the near future will be used for direct marketing in the U.S. of European pharmaceutical innovations. Should Japanese firms attempt to make a similar entry to the U.S. market, the panel points out, fewer appropriate small firms will now be available.

Why have these changes occurred in the U.S.'s competitive position? The panel identifies two sources: factors general to the U.S. economy, and causes specific to the pharmaceutical industry. The report notes that there are numerous similarities between the drop in pharmaceutical industry competitiveness and the relative decline of the U.S. economy and of other U.S. industries, including other high-technology industries, compared to Japan and Western Europe.

However, the panel emphasizes, in two respects the pharmaceutical industry's competitive position has declined more severely than other U.S. industries, because of factors unique to the industry. First, there has been a "precipitous drop" in the proportion of world drug production located in the U.S., "a decline wholly unmatched in other segments of the chemical industry."

The explanation is more rapid growth of demand for pharmaceuticals abroad than in the U.S., coupled with widespread foreign nontariff barriers (such as discriminatory safety and pricing policies) that effectively require domestic production. Major U.S. firms have adapted by building production facilities abroad. Thus, the decline in worldwide sales is much less severe than the drop in U.S.-located production. But it means loss of jobs and income in the U.S.

A second and even more important trend unique to the industry is the drop in the U.S. share of world pharmaceutical R&D spending by half, "markedly more severe" than for any other U.S. industry. By contrast, the U.S. share of world chemical R&D spending has fallen only a few per cent. The panel concludes government policies are the most likely cause—"both U.S. government policies that relatively discourage pharmaceutical innovation and foreign policies that relatively encourage innovation abroad."

The panel therefore suggests several policy steps to counteract the decline in U.S. competitiveness. In the trade area, it suggests development of "an appropriate U.S. response" to foreign trade (nontariff) barriers favoring their domestic products. It also suggests changing Food & Drug Administration policy prohibiting the export of new drugs not yet approved for sale in the U.S.—even if already approved abroad—thus giving U.S. firms an incentive to transfer pharmaceutical technology abroad and produce the new drugs there. Such new drugs could be exported as finished chemicals not specifically labeled for new drug use, it notes.

In the patent area, the panel suggests legislation to restore the time lost from the 17-year life of a patent as a result of FDA regulatory requirements. The report suggests reconsidering antitrust policy to determine if it discourages mergers of small and midsize firms that would make U.S. pharmaceutical firms more competitive globally. The panel also proposes expansion of research tax credits to include research-related expenditures not now covered.

The panel says that the impact of product liability rules on the industry and its innovation should be studied to try to reduce "this disincentive to research." And in the regulatory area, the panel supports implementation by FDA by administrative action, as rapidly as possible, of recent recommendations by the Commission on the Federal Drug Approval Process to speed up the drug testing and approval process.

Copies of the 106-page report can be obtained for $8.95 prepaid from the National Academy Press, 2101 Constitution Ave., N.W., Washington, D.C. 20418. The project was supported by a grant from the National Science Foundation. □

Japanese a growing force in world drug industry

In its study of the U.S. pharmaceutical industry's international competitiveness, the National Academy of Engineering panel tried to assess prospects for technological change and future industrial development. One major trend it points to is the growing innovational significance of Japanese pharmaceutical firms.

Traditionally, Japan has not been a significant presence in world pharmaceutical markets, the report notes, because Japanese firms were not successful at innovation. In its development stage, the country's pharmaceutical industry focused on building domestic generic-type production, behind effective protective barriers against foreign imports, and was imitative rather than innovative.

However, since the mid-1970s, the approach has changed. R&D spending is increasing greatly (up from 6% of world pharmaceutical R&D spending in 1964 to 15% in 1978, for example). Moreover, the Japanese government has adopted policies providing incentives for research and innovation, and for international expansion.

The outcome of Japanese corporate and government policies is only now becoming visible in the world market, the panel notes—but the changes are "quite dramatic." For example, in 1981, Japanese firms ranked first in major new drugs introduced to world markets, with 17 out of 65 products. U.S. firms were second, with 13.

Furthermore, in 1982, Japanese firms obtained more than 16% of U.S. patents for pharmaceuticals and medicinal products, up from previous levels (2% in 1963, 6% in 1973, 9% in 1979). Japan received 38% of U.S. medicinal patents to foreign firms in 1982.

In addition, Japanese pharmaceutical firms are forming joint ventures with U.S. firms to market Japanese discoveries. Prominent are links between Abbott and Takeda, and Fujisama and SmithKline. "These linkages are clearly first steps toward direct marketing of Japanese products overseas," the panel notes.

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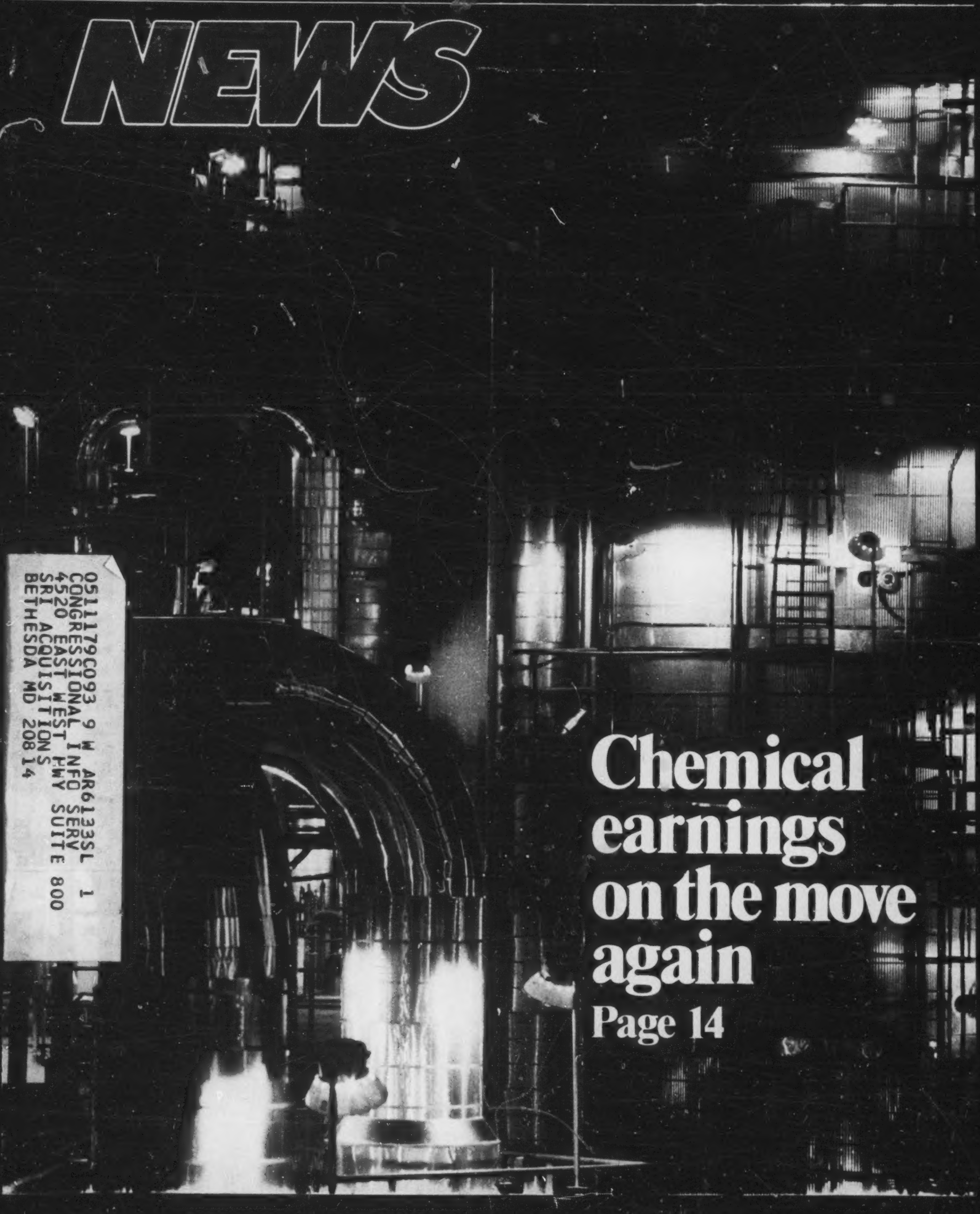
AUGUST 15, 1983

CHEMICAL & ENGINEERING NEWS



Chemical earnings on the move again

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Cover: Monsanto's new maleic anhydride plant at Pensacola, Fla.

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Canadian chemical firms' midyear statistics are hopeful; most are ahead of the 1982 pace in the second quarter. **Page 20**

Government

Though many problems are unresolved, such as waste disposal, gas deregulation, Congress takes five-week vacation. **Page 22**

Science

Interest in utilizing gold as a catalyst centers on areas such as hydrogen and oxygen transfer, skeletal rearrangements. **Page 25**

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Developing Countries: Challenge for Chemists, Economists

Deepening crises in global economics are forcing economists to draw on other fields of knowledge, such as chemistry, to help form their policy decisions

Wil Lepkowski, C&EN Washington

At the American Chemical Society's national meeting in Washington, D.C., later this month, a small group of ACS leaders will be getting together to chart new ways chemists can help developing countries solve their massive economic development problems. As University of Detroit chemist H. Harry Szmant says, "Chemistry is the only science devoted to transforming matter into useful products. It is the obvious means of bringing intellectual power to bear on satisfying the needs of society."

Szmant, who also heads the university's International Institute for Development through Chemistry, has been pressing for a closer integration of chemistry with economic development planning through 30 years of research and teaching in Latin America. But according to Szmant, economists don't appreciate how science and technology are changing the physical and cultural world. For if they did, they would insist in their policy advice on ways of supporting projects and programs that more directly meet the needs of human beings.

Nor, he feels, is economic thinking much of a factor with scientists and engineers in their plans to apply research and technology to developing countries. They think little of cost, price, feasibility, or cultural impact. It is as though both fields of thought pass each other in the night, even though neoclassical economics owes its foundation to mechanical concepts and metaphors founded on 19th century thermodynamics, a fact forgotten by almost everyone who writes about economics, yet a fact crucial to understanding why economists think in the mechanical ways they do.

C&EN staff photos

Urquidi: economics is inadequate

Few people have much faith in economists these days. But that hardly means economics is irrelevant. Economic advice controls policy. And since economists give policy advice, their views of the world are indeed important especially if it is science and technology that are the key elements in global change. Indeed, as one wag says, economists themselves are defying the market laws they expound. The worse their performance, the more they are in demand.

Fortunately, there is a growing tide of unrest within the economics profession itself over these matters. The concerns began with the realization that most economic forecasts made after oil prices rose with the 1973 Arab oil embargo turned out wrong. Now that oil prices may well be fluctuating over coming years, the profession is even more disturbed. Inflation and unemployment spin out of control in one country. Interest rates soar in another. Exchange rates fluctuate dizzily. Meanwhile, agricultural development declines in precisely those countries that need it for basic survival.

Then there is the $600 billion debt owed to western banks and international lending institutions. Brazil owes $90 billion, Mexico $83 billion, Venezuela $32 billion, Chile (a country with a population of only 11 million) $22 billion. All these countries borrowed on the presumption that their economies would grow through exports of their commodities and manufactured goods. But nothing of the sort hap-

IFIAS plots research program assessing relevance of economic theory to world changes

Part I. The Relevance of Economic Theory to Policy.

A series of commissioned papers on such topics as the role of noneconomic factors in environment; security, ideology, and science as factors in economic policy; the usefulness of short-term economic policies as practiced by the developed countries; prospects for cooperation between developing countries; and relations of the communist economies to those of developing countries.

Part II. Selected Areas of Socio-Economic Transformation:

1. Toward a Socio-Economic Theory of Technological Change. What are the long-run impacts of high technology on society, including the continuing mechanization of agriculture? How has the rise of transnational corporations affected consumption patterns around the world? Do the transnationals really boost the economic and social well-being of the host countries?

2. Using the Human Resource: Labor Costs and Emerging Patterns of Occupation. Full employment now may be an unachievable myth in industrial countries. Will there emerge new patterns of occupation such as shortened workweeks, earlier retirement, or later entrance into the job market, or temporary opportunities to withdraw from the labor force? Do macroeconomic policies such as monetary and fiscal measures deal adequately with the long-term problems of unemployment in Europe and other industrial countries?

3. Adjustment to the Changing International Division of Industry. New industries are spreading all over the world, sparking sharp changes in the global "division of industry." One result is the upsetting of trading rules and confusing the meaning of comparative advantage. Traditional theories of trade thus should be re-examined to broaden their range of application. To what degree, now, is knowledge a factor in trade flows? Labor and capital no longer seem the primary determinants. Other factors besides labor costs appear now to be determining in what country goods are produced. Finally, what will happen when the oil-producing countries become exporters of products of large, capital-intensive products?

4. Development strategies: Critical Review and Alternatives. Development theories applied over the past decades seem to have failed. Import substitution, fluctuating terms of trade, and land reform as bases of these theories no longer seem to be valid as development strategies. Should new development theories be based on such practical domestic policies as reforestation, conservation, and new technologies? What are other alternatives?

5. New Global Interactions Among the Developing and Centrally Planned Economies. Should trade be expanded among developing countries? Should they give preferential treatment to each other's products? What would be the political obstacles to a customs union?

6. Peoples' Access to Food. With farm productivity increasing in the North and population soaring in the South, present patterns of agricultural trade are certain to intensify. Is this pattern socially desirable? Will local production be inhibited? Would risks of famine be enhanced? To what extent is lack of agriculture in some southern countries caused by counterproductive economic and social policies?

pened. The global economy fell into recession. Much of the lent money went into real estate investments by the upper classes, or into consumer loans for members of the lower class, who promptly lost their jobs and became personally bankrupt. Meanwhile, the poor in each of the countries got poorer. Chile, which adopted a free market policy based on the Chicago school of conservative economics expounded by Nobelist Milton Friedman, went into a severe tailspin beginning in 1981.

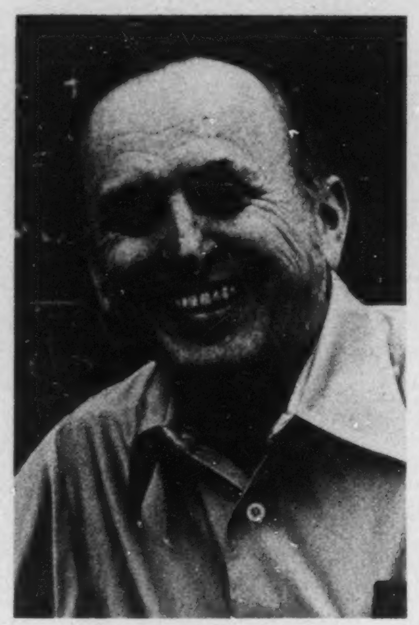
The roots of all these problems may have nothing to do with economics as it is practiced as a theoretical field. But dismissing the social responsibilities of economists could well be an intellectual cop-out. The central banks and the International Monetary Fund in Washington have to accept much of the blame for the current global crisis. Economic advisers cannot escape blame when they see Venezuela's agricultural college virtually boarded up while the country experiences food shortages and expensive food imports.

The concern basically is that macroeconomic theories often bear no relation to the realities of human behavior, or to sustaining the world's natural life support system, or caring about the quality of village life. Without a rethinking of economic theory through a more thorough integration with technical change, the advice that economists give to governments, industry, and consumers could well continue to spin the world toward deeper crises.

The chore, then, is twofold: first, for science to be a more significant part of economic planning. Second, for economists to draw on other fields of knowledge to improve the basis for their policy decisions.

In June, an unusual meeting was held at the Rockefeller estate at Pocantico Hills near Tarrytown, N.Y., expressly to deal with these issues. The meeting called together members of the International Federation of Institutes of Advanced Study. Its theme was laid out in a basic issues paper by Victor L. Urquidi, a former chemist but now an economist and president of El Colegio de Mexico. In it he asked, "Why is economics as practiced today in different kinds of societies so inadequate in response to prospects and visions of the future held by people at large? Large numbers of economies are undergoing deep crises. The crises can be characterized as not only economic but social and political. The sum of all the crises adds up to a serious global crisis to a degree not experienced before in modern times."

Then he asked: "Is traditional economics relevant? Most western economists carry out their research on conditions in the highly industrialized countries, and assume the findings are applicable to developing countries. Most economists in general tend to favor 'general equilibrium' analysis—disturbances in the system that can be corrected through the market or otherwise. Everything bounces back sooner or later, back into balance."



Zajak: more interaction now

But everything doesn't bounce back into balance. And that being so, Urquidi claims that most of his fellow economists have been impervious to the impact of technological change on society, and frequently have assumed that technology—even the massive amount spent on weapons technology—is developed as a result of "market forces." The developing countries especially find themselves at a particular disadvantage, he says, in that their economic resources are too small to invest in the innovations they need.

After a week of hashing out such issues as the global food supply, overpopulation, ecological problems, the impact of automation on jobs around the world, the threat of protectionism, and sundry other issues, they went home to their respective research centers to think about their research agenda. Late last month, the agenda was released.

What economists can agree on now is that the world is increasingly, probably irretrievably, interdependent. Money, technology, and the "transnationalization" of industry with its enormous impact on management, transfer of technology and information across borders, and the changes that affect traditional cultures and economies have made it so. And it has been that interdependency that ironically has widened the gap between the rich and poor countries.

"Interdependency is a wonderful word and a marvelous sentiment," says Howard Perlmutter of the University of Pennsylvania's Wharton School of Economics. "But being interdependent with 159 other nations is also turbulent, confusing, and very disturbing. You can't export the same things to each other. There already are 32 million unemployed people currently in industrial countries. With computers and robotics, why do we think we'll need more people for that kind of work? The factory of the future, the office of the future, are really less people-intensive." Perlmutter made his remarks in a panel discussion produced by author, lecturer, and economic critic Hazel Henderson, prepared for public television on WUFT in Gainesville, Fla., as part of a new series entitled "Creating Alternative Futures."

The international chemical community is finding itself moving into the thick of these debates over economic values, too. The International Union of Pure & Applied Chemistry has established a series of conferences known as CHEMRAWN, or Chemical Research Applied to World Needs. And two years ago, the United Nations Educational, Social & Cultural Organization established the International Organization for Chemical Sciences in Development. Its president is chemist Glenn T. Seaborg of the University of California, Berkeley (C&EN, Jan. 3, page 21).

One of IOCSD's goals is to help the developing countries establish small-scale chemically related industries, no small economic undertaking. Seaborg says the organization, now involving hundreds of academics and industrialists all over the world, hasn't yet integrated macro- and microeconomic thinking into its plans. "We're still a small, undermanned, underfunded organization," he says, "but it's something we'll have to get around to."

CHEMRAWN's first conference, meanwhile, was held in Toronto in 1981 on finding organic substitutes for petroleum. The second was held at the end of last year in Manila on world food supplies, and its report was issued late last month (C&EN, Aug. 1, page 4).

CHEMRAWN, through continuing followup of past meetings and through the planning of future meetings, undoubtedly will be a powerful force in pulling together into one network the world chemical community into economic development dilemmas. But much will depend on the speed with which the economic implications of chemical knowledge pervade economic thinking, and vice versa. This, at least, is what Louis G. Nickell, vice president for R&D at Velsicol Chemical Co., believes. Nickell is on the future actions committee of CHEMRAWN II and has intimate knowledge of the problems of development in developing countries. He agrees that such things as social and technical changes have to be incorporated into any discussion of technology transfer into the economies of developing countries.

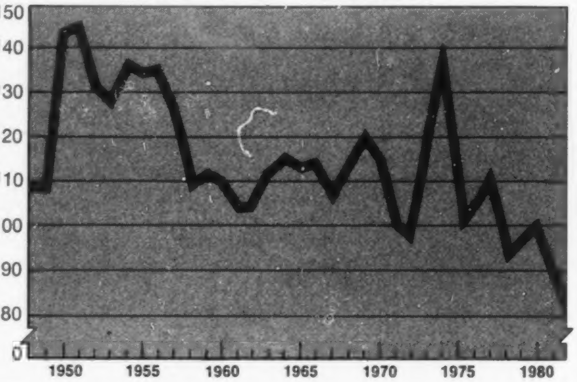
"I think it would be a good idea for a followup CHEMRAWN conference to discuss these issues and get a good dialogue going between chemists and economists," Szmant says. "What we technical people need to do is ask them the right questions, such as how we're going to do what we want to do, how much it will cost, and at what social cost. We don't ask those questions enough. But we'd not want just theoretical economists. We'd want ones who can visualize the consequences of each project, then determine the various costs."

Chemist Cyril Ponnamperuma of the University of Maryland, a native of Sri Lanka but now a U.S. citizen, is cochairman of the future actions committee of CHEMRAWN II. He agrees with Nickell that a deeper dialogue with development economists is a logical next step. But he would go a step further and consider the cultural aspects of technical change. Economists would need that data, too. "Who would have thought that the current issue disrupting my country would be linguistic? [Riots over language policies] recently flared in Sri Lanka between mobs of majority Sinhalese and the Tamils, of Indian origin.

Developing countries face worsening export, debt problems

Prices of commodity exports have fallen severely

Composite commodity index, 1977–79 average = 100[a]

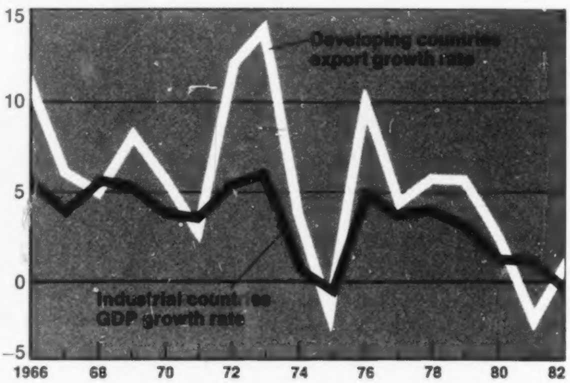


[a] The graph shows nonoil commodity prices adjusted for the price of manufactures imported by developing countries. The commodities are coffee, cocoa, tea, maize, rice, wheat, sorghum, soybeans, groundnuts, palm oil, coconut oil, copra, groundnut oil, soybean meal, sugar, beef, bananas, oranges, cotton, jute, rubber, tobacco, logs, copper, tin, nickel, bauxite, aluminum, iron ore, manganese ore, lead, zinc, and phosphate rock.

Commodity exports are the lifeblood of developing countries' economies. Yet, commodity prices have fallen to only 80% of the 1977–79 average. This speaks for the need for developing countries to manufacture more value-added products of these commodities. But the richer countries might not import these products

Export volume growth is declining with GDP growth of industrial nations

Annual change, %



Sources: World Development Report 1983, World Bank

The growth of all exports from the developing countries has gone down steadily since 1976, along with the gross domestic product for the industrial countries. The graph shows how the rises in industrial country growth rates produce corresponding rises in developing country exports. No one knows what will happen when the developing and industrial countries compete more and more for the same products. Perhaps developing countries should not industrialize along the same patterns as the industrial world, but rather choose a different pattern of technology

Ratios of debt service obligations to exports have soared

Debt service obligations are the most daunting problems facing developing nations, because these bear direct connections to their dependency on industrial countries' financial systems. Debt service obligation ratio is the proportion of the amount of interest that developing countries must pay to lending institutions to [illegible] of their exports. That means that in the case of Latin American countries, 53% of their export earnings goes simply to payment of interest on their loans. The principal may never be repaid

Country group	1970	1980	1981	1982
ALL DEVELOPING COUNTRIES	**13.5**	**13.6**	**16.3**	**20.7**
Low income				
Asia	13.3	7.9	8.4	10.1
Africa	6.5	8.8	11.6	28.3
Middle income				
Oil importers	14.0	14.9	18.0	23.0
East Asia	6.7	7.0	7.6	8.6
Latin America	13.0	33.3	39.6	53.2
Oil exporters	13.9	13.0	15.7	19.1

Ponnamperuma feels the rich North and the poor South are continuing to move apart economically and he sees little way out. Even the development of something called the winged bean plant as a substitute for soybeans would cause economic or at least political disruption in Brazil and the U.S., big exporters of soybeans. But Ponnamperuma believes that the enormous potential of high technology can be wed to village economics.

"So much can be done," he says. "These countries can leap into the 20th century." But the problem, he acknowledges, is that these developments are geared toward a better balanced village life, not toward lifting whole countries out of their massive debts and general agricultural inertia. It means little to International Monetary Fund economists that a country's people are well fed and housed on localized farming, fishing, and thatch construction. Those activities add almost nothing to the gross domestic product of the country. Thus, IMF's macroeconomists virtually ignore the local human welfare issues. But it is those issues that lead most to social unrest and longer-term economic problems.

Albert C. Zettlemoyer, recently retired from Lehigh University, and a former president of the American Chemical Society, just returned from Nairobi, Kenya, where he attended the Second International Chemistry Congress in Africa. But again, Zettlemoyer observed that no discussions were held on the economics of applying

Detroit's Szmant: chemists must get involved with developing countries' economic problems

One chemist who has wrestled with the problems of development since the 1950s is H. Harry Szmant, chairman of the chemistry department at the University of Detroit. A physical organic chemist, Szmant has done research and taught throughout Latin America, beginning with Cuba, extending through Puerto Rico and Venezuela, and these days involving Chile and Brazil. Recently he shared some of his observations with C&EN.

C&EN: After all your years of trying to insert better chemical thinking into development problems in Latin America, what are some of your conclusions as to the role of chemists and their engineering in those challenges?

Szmant: I think the potential role of the chemical community is tremendous, because in view of the lack of recognition for chemical science and technology, chemists must get involved in solving the fundamental problems of economic production and productivity of developing countries.

Since the chemical science and technology input isn't so strong, someone has to get up and make these things clear. Who but the chemical community? I come from an industrial chemistry background and so I believe that until we have a reservoir of human resources that are programed in the educational experience to think in terms of economic development, all the jetting around the world to talk about research is mere window dressing.

C&EN: Can you give an example of the problems you talk about through a specific country?

Szmant: Let's take Chile. Chile is a highly civilized, Europe-oriented country with more than 95% literacy. It has the highest per capita concentration of Ph.D. chemists of any Latin American country. Against that, Chile imports millions of dollars of goods that by all rhyme or reason should be made in Chile itself. It is the second largest provider of timber on the continent, yet it imports things like lignin derivatives, and so on. This simply proves that much of what's going on in Chile has little relevance to the problems the country has as a whole. Chile will remain undeveloped until agriculture, forestry, and other fundamental sectors get technified. And who is going to technify them? Some economist from the World Bank? All they do is give money. We have to provide the intellectual resources.

C&EN: Didn't Chile attempt a major free market experiment that seemed successful for a while?

Szmant: We know what happened to that experiment. I sent Milton Friedman, the University of Chicago economist who was the godfather of that policy, a letter trying to describe the importance of the chemical sector to the economy. In his reply, he said there was no such thing as a key industry like chemistry. He said the chemical industry's importance was shared appropriately by its share in the GNP, just as the importance of other economic activity is measured likewise.

What's wrong with that? I'll tell you. Let's say beauty shops and physical fitness establishments made up a pro-

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the ideas at the meeting. "The business of the distribution of knowledge was never addressed," he says, although the scientific content of the meeting was more than adequate. "There was a lot of lack of understanding there on those matters."

He believes chemists involved in discussions on technology and development know enough about economics to discuss costs and benefits, but that economists need a deeper understanding of science and technology. "Clothing and shelter are now largely synthetic in those countries," he observes, "but food almost not at all. We may have to go that way in the poorest places just to keep the people alive in the year 2000, especially when you consider that 50% of the food shipped or grown in those places gets spoiled before reaching anyone. There's no connection between delivery and consumption."

Zettlemoyer observes that village people are totally out of the information loop when it comes to knowing about sources of help. But he agrees that it is at the village level where development must start. E. F. Schumacher addressed these issues in his book, "Small Is Beautiful—Economics as though People Mattered." Zettlemoyer, who has seen African villages, says he is familiar with the principles Schumacher expounded on the importance of small-scale technology at the village level. "I thought that was good stuff, because that's touching the problem where it is."

Economic critic Henderson is a disciple of Schumacher herself. It is the quality of life that needs to be put into the economic equations, along with balance of payment and production statistics. The point, she says, is that the indicators of well-being for the developing countries cannot be the same as those given for the industrial countries, because the patterns of industrial development simply may not be transferable. "The goals of these countries should be toward a basic inner structure that ensures that basic human needs are met first," she says. "We are in a fix because IMF will insist that the debtor countries establish policies that are aimed at achieving industrial rather than agricultural growth."

The dilemma was illustrated by Wharton's Perlmutter during his discussions with Henderson. "Let's say Zaire comes to the World Bank for a $2 billion loan for an aluminum plant. The bank is not likely to say, 'Why don't you spend it on villages, or get barter going?' It won't show up in the numbers indicating economic progress. Rather than let Zaire get into the grub of the world aluminum problems, because they have to sell it after they make it, maybe there are other ways to reward other concepts of development than largely westernized concepts.

"With very few resources, what do you do in those countries when you also include the mobilization of villages for health care and nutrition, or a mixture of cash crops and subsistence? I think these are really current ideas, because those motorcycles the villagers want

portion of the GNP equal to the chemical sector. Would the nation suffer an equivalent decline if only beauty shops and health clubs decline? Although the free market economy is the best approach to the promotion of economic growth, it must be handled with some restraint during the transition from semidevelopment to development. Otherwise, the social, political, and economic adjustments may be excessive.

The problem with the so-called Chicago Boys is that they took a textbook and said, "Friedman says to open the doors and let everything in." The first thing my chemistry hosts did during a visit recently is take me to a supermarket to show me what was on the shelves: Swiss, West German, American imports were all over. Then we went down the road the next day to the valley. The sugar beet factory was closed because sugar was being imported from all over.

The trouble with economists is that they don't look at real life. They look at models. Let the best man win. Let the poor competitors go under. The trouble with that is it's a formula for revolution.

C&EN: Well then, what's wrong with economics that can be put right?

Szmant: The economists obviously don't have the answers. Obviously, since World War II, they have had enough chances to prove the validity of their theories. You can use a perfectly normal and traditional economics to get the beginning of a process going. In chemical kinetics, every reaction rate follows a steep upward slope before leveling off. You can get economic growth like this achieved easily, like raising the output of oil from 10 to 13 barrels. That may be 30% growth, but usually if you try to go higher you run into some problems.

You can get high economic turnover in a developing country by building roads, dams, water supplies, and all the rest. They are easy to do. In fact, you can even install steel mills and refineries by shipping in whole plants on barges. But then the question becomes how you integrate this infrastructure with further progress that really affects the masses of people. That has not been addressed.

C&EN: Okay, so what path do they take?

Szmant: Shift from commodities to specialty chemicals. By doing that you get value-added products in such areas as specialty chemicals, lubricants, plasticizers, detergents, and the like. In many cases, the industrial countries no longer have an interest in developing those products. Otherwise, the developing countries remain stuck with exporting cheap copper or bananas or coconuts.

when they see them aren't coming around the corner very quickly."

Edward E. Zajak, head of the economics department at Bell Laboratories in Murray Hill, N.J., says economists indeed are beginning to look into social, philosophical, and ethical issues as they impart their advice to governments. "There's a great deal of interaction now," he says, "between philosophers and economists in questions like how you define justice—basic ethical questions—which gets back to the problems of distribution of income and labor. Economic man is so jam-packed with information that choices aren't that simple anymore. And that may be one of the new frontiers of economics. There is some concern that people on both sides of the market don't have the same amount of information."

But Zajak cautions critics not to be too tough on economists. Their theories have worked in the past, and they adapted creatively to changing social and technological conditions, right through such giants as Smith, Malthus, Ricardo, Marx, Pareto, Marshall, Keynes, and Schumpeter. The major economic figures had their models, and those models worked for the conditions of the time. And to Zajak, that should not be a cause for complaint. The field, he believes, does keep up. Its models are roughly sufficient.

"The simple linear theory you're taught in strength of materials as an engineer," he explains, "is a very simple one that works. It only crudely approximates the actual stresses of materials. But because it is crude doesn't mean you throw the theory out and go only with very complicated, sophisticated theories." So also for economic models.

Still, classical economics was grounded on metaphors supplied by the thermodynamics of mechanical engines. The textbooks tell one that. And some think that economics needs a more up-to-date metaphor drawn from today's scientific thinking. Zajak's former boss, William O. Baker, retired president of Bell Labs, agrees.

"We know," Baker says, "that the models of the machine today's neoclassical economics is built upon are completely unrealistic in a day of automata and computers. So the frames of reference, the mind sets of conventional economists, are probably wrong. They have to go back to school and get trained in new things."

One aspect Baker mentions that appears fascinating is that when economics was born, there was no understanding of what has since become the concept of social entropy. In short, society is entropic when there is a lot of "wasted" motion in getting work done. Modern communications, information, and computer science has made it possible to speed the activities of people and their handling of data and processes. There is a definite hidden economics to this process, with numerous implications, likened to the idea that the expansion of knowledge, or information, is, with love and religious faith, a form of energy that does not dissipate on use. (The Pocantico economists, in fact, did, if whimsically, mention the underused quality of "amour" in the development of sound economic policies.)

To Baker, social entropy is diminished and even reversed by the kind of revolution he helped spearhead at Bell. He calls the upshot the "organization of knowledge for action," and adds that it certainly "puts a different cast" on economics.

One example is the way the computer and telecommunications have accelerated international banking transactions and refined investment strategies. "But you also see it on the assembly lines of plants and on the merchandising of goods," he says. "These are determined by databases along such factors as the colors of textiles or the shape of bottles for successful marketing. The cost of achieving variety has become greatly reduced because of these antientropic elements."

Chubin: economics isn't to blame

Author Paul Hawken, president of the tool-making company, Smith & Hawken Ltd., says the next economy is the "informative economy" explaining that as societies and industries are forced to become more energy efficient, the amount of information they require for doing that rises if one hopes to maintain one's standard of living.

"The critical difference between now and 20 years ago," he says in his just published book, "The Next Economy," "is that the manufacturer no longer can use just energy to increase his productivity. It's too expensive. Instead, the manufacturer has to become smarter at what he does."

So an informative economy, says Hawken, uses less mass by incorporating durability, quality, and conservation of materials into the products it makes. Such material is "value added," containing "far more information" than energy-efficient material.

"In an informative economy," he writes, "we change from an affluent to an influent society. If you are affluent, goods and services flow toward you; if you are influent, the information contained within goods flows into you. An affluent society may possess an opulent and abundant amount of goods, but that does not mean it will be able to utilize, appreciate, and maintain them. An influent society will have less, but its relationship to what it has will be more involved and concerned; people will take care of what they have, and what they have will mean more to them. In other words, an affluent society amasses goods, whereas an influent society processes the information within goods."

Hawken points out that "mass economy" governments need to begin understanding information as an economic policy principle. "The role of the government has been to keep the economic kettle boiling, primarily through monetary and tax policies," he says. "The U.S. government, like big business, has defined its role as the gatherer and keeper of information rather than the distributor of that information to society." What this new kind of thinking does is force consideration of the human value issues in the application of technology for development. A program at the World Bank under technology advisers Charles Weiss and Mario Kamenetzky is attempting to do just that: to educate economists about the role of technical choice in economic policy.

"It's a matter of making decisions that are optimal for the society," says Kamenetzky. "Choices forced by macroeconomic thinking are often not optimal because they respond to distorted signals from macro policy makers. What these countries are refusing to study is where is the appropriate balance between large-scale projects and successful village economies. Successful village economies, which often can incorporate sophisticated small-scale technologies, don't make up a significant proportion of a country's gross domestic product. So the macroeconomists at the International Monetary Fund, intent on developing an industrial infrastructure in a country, tend to play them down."

Kamenetzky sadly comments that the trend of technical thinking has been moving away from human values in the economic and technical scheme. "In 1972 I attended a meeting of chemical engineers in Paris. The theme was chemical engineering in the service of mankind, and there was considerable discussion of human value issues at it. But we have been moving backward since then. After the price of oil rose in 1973, all subsequent meetings had to do with improving the efficiency of production. The human value issue vanished."

Daryl E. Chubin, director of the technology and science policy program at Georgia Institute of Technology, thinks, as a social scientist, that the basic issue is shifting economic analysis in the direction of assessing the concept of equity on a global scale. "What I hear," he says, "is questions like whose planet is this anyway? Who has the right to what's on it? This is opposed to the current concepts of having a group of people in control of one set of resources, discussing how they control or manipulate them. The question, though, is how we can distribute them for their greatest benefit."

One of the things that eclipses everything else, Chubin feels, is that economics is a well-entrenched profession. Disciplines tend to put blinders on people and thus the experts need other disciplines to help them see the problem. "In a way, it's wrong to say that economics is to blame," he says. "Instead, we probably need to say we need new intellectual coalitions." ☐

Chemical Earnings Beginning To Turn Around

William J. Storck and David Webber,
C&EN New York

The U.S. chemical industry's earnings have started to turn around, but there is a long, steep way to go before the chemical industry reaches performance matching its peak years. The industry is moving, but slowly.

Sales and earnings at major chemical companies in the second quarter, plus those at oil and diversified companies, show little growth from the same period a year ago, but chemical producers are heartened that the days of the big earnings declines seem to be over. And growth from the first quarter is very good indeed.

As a result of increased consumer demand, production of chemicals and allied products has increased more than 8% in the second quarter compared to the year earlier period.

The lag is in prices, which are still down about 1% from second-quarter 1982. However, even this gives a ray of hope for the chemical industry. With the increase in production, the lagging effect of prices will give the industry a lot of earnings leverage when tabs begin to turn around. And this turnaround is probably going to get a push in the third and fourth quarters. Already producers are saying that supply of some products, especially plastics, is beginning to get tight. This tightness in the market will easily facilitate price increases throughout the industry.

For the second quarter, combined results for 30 leading chemical companies were essentially unchanged from a year ago. Combined sales for the 30 companies totaled $17.4 billion, which was essentially the same as in the second quarter of 1982.

Chemical industry leaders for second-quarter 1983 . . .

Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1982		$ Millions	Rank 1982		Earnings as % of sales	Rank 1982
1	Dow Chemical	$2728.0	1	Monsanto	$114.0	2	International Flavors	16.6%	1
2	Union Carbide	2180.8	2	Dow Chemical	93.0	3	Freeport-McMoRan	11.2	2
3	Monsanto	1613.0	4	PPG Industries	63.0	5	Nalco Chemical	11.2	3
4	W. R. Grace	1605.6	3	Union Carbide	61.5	1	Lubrizol	9.6	6
5	PPG Industries	931.2	6	Rohm & Haas	43.1	6	Loctite	9.1	8
6	American Cyanamid	897.4	5	American Cyanamid	42.9	6	Rohm & Haas	8.3	13
7	Celanese	834.0	7	W. R. Grace	40.5	3	Chemed	7.6	6
8	National Distillers	663.2	11	Hercules	35.2	11	Petrolite	7.6	4
9	Hercules	634.0	8	Ethyl	28.9	8	Monsanto	7.1	8
10	Rohm & Haas	521.4	9	Air Products	27.1	17	First Mississippi	7.0	11

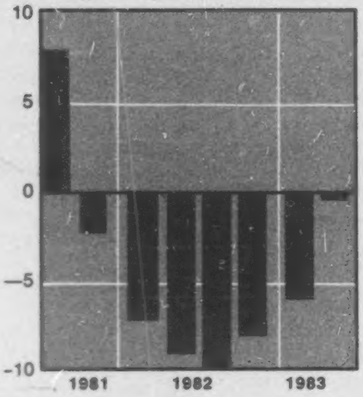
. . . and for first-half 1983

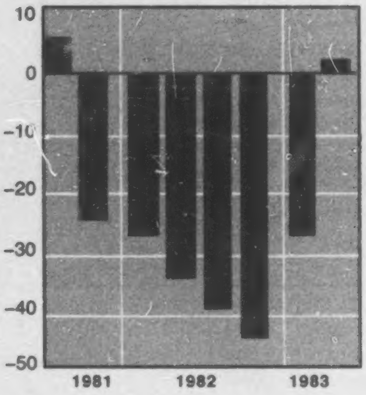
Sales				Earnings[a]			Profitability		
Rank		$ Millions	Rank 1982		$ Millions	Rank 1982		Earnings as % of sales	Rank 1982
1	Dow Chemical	$5266.0	1	Monsanto	$215.0	1	International Flavors	15.9%	1
2	Union Carbide	4371.6	2	Dow Chemical	147.0	3	Freeport-McMoRan	10.8	2
3	Monsanto	3101.0	3	Union Carbide	109.6	2	Nalco Chemical	10.8	5
4	W. R. Grace	2959.8	4	PPG Industries	95.0	6	Lubrizol	9.3	9
5	PPG Industries	1800.0	7	Rohm & Haas	76.8	12	Loctite	8.9	12
6	American Cyanamid	1722.7	5	American Cyanamid	70.1	7	Petrolite	8.3	4
7	Celanese	1600.0	6	Hercules	59.7	11	Rohm & Haas	7.8	17
8	National Distillers	1250.3	10	Air Products	51.7	8	Chemed	6.9	7
9	Hercules	1236.0	8	Ethyl	49.1	10	Monsanto	6.9	8
10	Rohm & Haas	983.4	9	Olin	46.6	9	Air Products	6.2	10

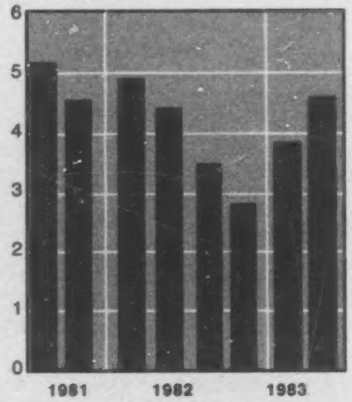
[a] After taxes. **Note:** For 30 companies listed on page 16.

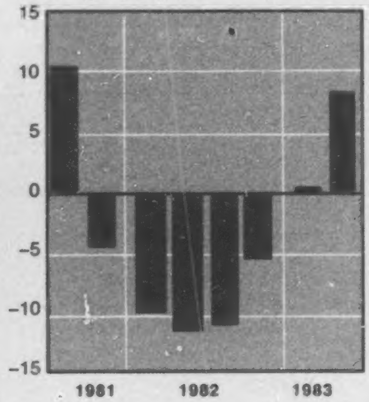
Chemical industry 1983 second-quarter results

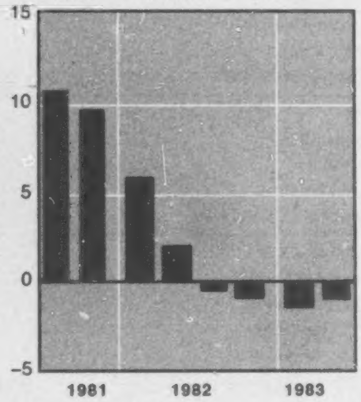
- Sales down slightly
- Earnings finally rise
- Profitability rises to 4.6%
- Production is up 8.1%
- Prices are still down


Sales
% change from year-earlier quarter

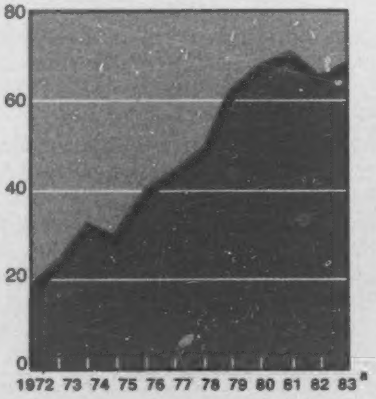

Earnings
% change from year-earlier quarter

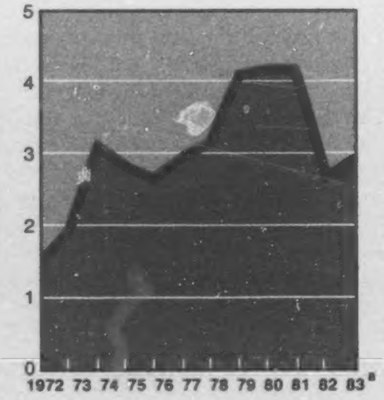

Profit margins
After-tax earnings as % of sales

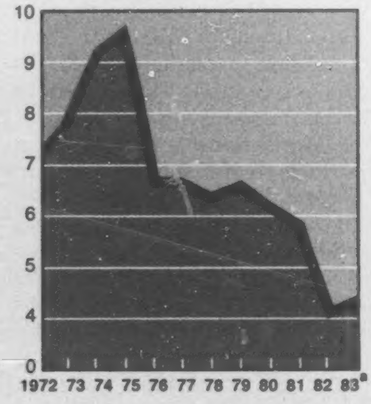

Production
% change from year-earlier quarter


Prices
% change from year-earlier quarter

Sales in 1983 will increase 8% and earnings will rise 12%, pushing profitability up to 4.2%


Annual sales
$ Billions


Annual earnings
$ Billions


Annual profit margins
After-tax earnings as % of sales

[a] C&EN estimates. **Note:** All sales, earnings, and profit-margin data are based on the combined performance of the 30 chemical companies listed on page 16.

Days of double-digit earnings declines for chemical industry seem to be over

	SECOND-QUARTER 1983						FIRST-HALF 1983			
	Sales	Earnings	Change from 1982		Profit margin[a]		Sales	Earnings	Change from 1982	
	($ millions)		Sales	Earnings	1983	1982	($ millions)		Sales	Earnings
Air Products	$ 415.9	$ 27.1	9%	82%	6.5%	3.9%	$ 829.9	$ 51.7	6%	−3%
American Cyanamid	897.4	42.9	−2	53	5.1	3.1	1722.7	70.1	−1	6
Celanese	834.0	21.0	6	17	2.5	2.3	1600.0	27.0	−2	−29
Chemed	65.0	4.9	0	23	7.6	6.2	125.5	8.6	1	−7
Crompton & Knowles	60.8	2.1	9	62	3.5	2.3	115.2	3.4	5	62
Dow Chemical[b]	2728.0	93.0	0	21	3.4	2.8	5266.0	147.0	4	−16
Ethyl	447.9	28.9	7	3	6.5	6.7	843.7	49.1	3	9
First Mississippi	64.2	4.5	3	29	7.0	5.6	111.2	6.2	−2	−28
Freeport-McMoRan	186.2	20.9	6	−8	11.2	12.9	390.4	42.0	6	−15
H. B. Fuller[c]	110.8	3.6	34	20	3.2	3.6	206.3	5.4	33	35
W. R. Grace[d]	1605.6	40.5	−2	−47	2.5	4.7	2959.8	73.6	−5	−53
Hercules[e]	634.0	35.2	−3	58	5.6	3.4	1236.0	59.7	−4	35
International Flavors	126.3	21.0	2	6	16.6	16.0	247.8	39.3	2	4
International Minerals	438.4	13.2	9	71	3.0	1.9	810.0	34.4	−1	22
Loctite	57.2	5.2	5	63	9.1	5.9	112.6	10.0	3	54
Lubrizol[f]	211.3	20.3	−4	49	9.6	6.2	395.8	37.0	−5	27
Monsanto[f]	1613.0	114.0	−1	19	7.1	5.9	3101.0	215.0	−8	−12
Morton-Thiokol[g]	446.4	19.7	—	—	4.4	5.8	902.0	43.1	—	—
Nalco Chemical[h]	164.2	18.4	−1	12	11.2	9.9	323.7	34.9	0	10
National Distillers[h]	663.2	12.4	43	−44	1.9	4.8	1250.3	27.4	35	−30
Olin	490.3	24.0	3	3	4.9	4.9	963.4	46.6	−1	3
Pennwalt	246.5	6.9	−3	−37	2.8	4.3	484.4	13.2	−3	−23
Petrolite	72.3	5.5	−4	−25	7.6	9.7	144.2	11.9	−8	−25
PPG Industries	931.2	63.0	6	38	6.8	5.2	1800.0	95.0	13	36
Reichhold Chemicals[i]	194.8	6.6	−8	74	3.4	1.8	373.3	10.7	−11	51
Rohm & Haas	521.4	43.1	−1	54	8.3	5.3	983.4	76.8	−2	75
Stauffer Chemical[j]	291.4	3.2	−5	−82	1.1	5.6	655.4	30.7	−30	−80
Union Carbide	2180.8	61.5	−5	−48	2.8	5.1	4371.6	109.6	−5	−48
Williams Cos.[k]	392.8	19.0	−30	−14	4.8	3.5	762.0	27.6	−20	9
Witco Chemical[l]	343.4	12.4	2	39	3.6	2.6	666.4	23.0	−1	80
Total 15 largest companies[m,n]	**$14,847.5**	**$639.5**	**2%**	**2%**	**4.3%**	**4.3%**	**$28,639.8**	**$1126.1**	**−2%**	**−14%**
Second 15 companies[m]	**$2,587.2**	**$153.5**	**−6%**	**−1%**	**5.9%**	**5.7%**	**$5,114.2**	**$280.3**	**−9%**	**−14%**
GRAND TOTAL[n]	**$17,434.7**	**$793.0**	**0%**	**2%**	**4.6%**	**4.5%**	**$33,754.0**	**$1406.4**	**−3%**	**−14%**

[a] After-tax income as a percentage of sales. [b] Excludes $120 million nonrecurring gain in second-quarter 1982. [c] Excludes $900,000 extraordinary gain in first-half 1982. [d] Excludes $65.1 million nonrecurring gain in first-half 1982. [e] Excludes $11.8 million nonrecurring gain in second-quarter 1983. [f] Excludes $9 million nonrecurring charge in second-quarter 1982. [g] Since merger of Morton and Thiokol, previous figures have not been restated, making comparison with prior data meaningless. [h] Excludes net nonrecurring charge of $4.3 million in second-quarter 1982 and net nonrecurring gain of $7.2 million in first-half 1982. [i] Excludes nonrecurring loss of $900,000 in second-quarter 1982. [j] Excludes $8.7 million extraordinary gain in second-quarter 1982 and $10.6 million extraordinary gain for first-half 1983. [k] Excludes $16.6 million nonrecurring charge in second-quarter 1983. [l] Excludes nonrecurring charge of $1.5 million in sec-

Earnings, however, increased 2% to $793 million, ending six straight quarters of year-to-year declines in chemical income.

The larger companies on the list outperformed the smaller firms in the second quarter. Combined sales of the 15 larger chemical companies increased 2% to $14.8 billion; earnings increased a like amount to about $640 million. At the smaller firms sales and earnings continued to decline. Combined sales for the smaller firms fell 6% to $2.6 billion from year-ago levels, and earnings edged down 1% to $154 million.

The smaller firms continued to lead in profitability, however. Profit margins for the smaller companies in the second quarter averaged 5.9% compared to 4.3% for the larger firms. In the second quarter a year ago, the smaller firms had an average profit margin of 5.7% in contrast to 4.3% for the larger companies. For the 30 companies as a whole, profit margins inched up to an average of 4.6% in the second three months this year compared to 4.5% in the same period a year ago.

Though the second quarter looks flat viewed against results of last year, when compared with this year's first quarter, it seems very good indeed. Sales for the second quarter are up about 4% from the first quarter, but earnings are up more than 23%. This is in spite of a normal seasonal rise of 8 to 10% in earnings between the first and second quarters.

The quarter-to-quarter rise was due entirely to the performance of the 15 largest companies. Combined sales for this group increased 4.6% and earnings jumped 31%. For the group of smaller companies, sales were off almost 2%, whereas earnings managed to stay even with the first three months of the year.

For the first half, the gains of the second quarter have not erased the problems of the first. Combined first-half sales at the 30 companies were still off 3% from year-ago levels

FIRST-HALF 1983		12-MONTH RUNNING DATA			
Profit margin[a]		Change from 1982		Profit margin[a]	
1983	1982	Sales	Earnings	1983	1982
6.2%	6.9%	5%	−9%	6.5%	7.5%
4.1	3.8	−5	−26	3.8	4.9
1.7	2.3	−13	def	def	3.0
6.9	7.4	−1	−32	6.5	9.4
3.0	1.9	−4	−22	2.3	2.9
2.8	3.2	−3	−49	1.9	3.5
5.8	5.5	−4	7	6.0	5.4
5.6	7.6	−22	−4	7.0	5.6
10.8	13.3	−1	−10	12.7	14.1
2.6	2.6	19	−9	2.6	3.4
2.5	5.0	−7	−49	2.9	5.2
4.8	3.4	−8	−12	4.5	4.7
15.9	15.6	1	5	14.3	13.7
4.2	3.4	−11	−16	5.4	5.7
8.9	6.0	0	19	7.9	6.7
9.3	7.0	−6	−33	7.1	9.8
6.9	7.2	−7	−4	5.4	5.2
4.8	6.9	—	—	—	—
10.8	9.8	−4	−11	10.3	11.1
2.2	4.2	12	−49	2.8	6.1
4.8	4.7	−5	−17	3.5	4.0
2.7	3.4	−2	−37	2.2	3.4
8.3	10.0	−6	−13	8.7	9.4
5.3	4.4	4	22	5.6	4.7
2.9	1.7	−15	−14	1.7	1.7
7.8	4.4	−3	35	6.0	4.3
3.1	10.6	−19	−71	3.0	8.3
2.5	4.5	−7	−60	2.2	5.1
3.6	2.7	−19	−18	2.1	2.1
3.5	1.9	0	12	3.0	2.7
3.9%	**4.5%**	**−3%**	**−32%**	**3.3%**	**4.8%**
5.5%	**5.8%**	**−8%**	**−26%**	**5.1%**	**6.4%**
4.2%	**4.7%**	**−4%**	**−31%**	**3.6%**	**5.0%**

ond-quarter 1982 and net nonrecurring gain of $3.1 million in first-half 1982. m Division between large and small companies is about $400 million in second-quarter 1983. n Per cent change and profit margin averages exclude results of Morton-Thiokol. def = deficit.

to $33.8 billion, whereas earnings were down 14% to $1.4 billion. At the 15 larger companies, sales were down 2% to $28.6 billion and net income at $1.1 billion was down 14%. Combined earnings at the smaller companies were down 14% to $280 million; sales fell 9% to $5.1 billion.

Chemical executives generally seem satisfied with the second quarter and are buoyant about the remainder of the year.

At Dow Chemical, president and chief executive officer Paul F. Oreffice says, "In May, business started to benefit from the U.S. economic recovery and June was our best month since June 1981. One of the most positive points of the quarter was the increase we have seen in product volume." He adds, "Plastics demand was particularly strong with Dowlex linear low-density polyethylene leading the way."

Fibers sales also improved in the second quarter. Celanese chairman John D. Macomber says, "Our fibers business picked up strength," which was something of an understatement. Fibers earnings at Celanese in the second quarter were $1.03 per share, up more than 500% from 17 cents a share in second-quarter 1982.

Agriculture continued to have a bad effect on earnings, however. For example, at W. R. Grace earnings from the agricultural chemicals group in the second quarter this year were $1.6 million, down 86% from the second quarter of 1982.

Whether with the recovery under way companies are paying less attention to operations or they are more interested in improved demand, few chemical firms mentioned that they were achieving greater operating efficiencies.

Air Products was one firm that did mention cost containment. Chairman Edward Donley says, "Despite our optimism that the recovery now under way in the U.S. will continue, we are keeping a tight rein on costs. We are meeting our ambitious productivity improvement goals and are continuing to emphasize the long-term importance of productivity improvement."

Although few chemical companies mentioned cost containment, the same was definitely not true for the oil and diversified companies.

For energy companies and diversified manufacturers with chemical operations, renewed emphasis on efficiency and debt-reduction programs paid off well in the second quarter. The 26 biggest diversified manufacturers, for instance, eked out a bare 0.7% increase in sales revenue (combined) compared to the second quarter of 1982, but combined net income (minus nonrecurring gains and charges) rose a substantial 7.9%. Oil and gas company results give an even more marked testimony to the rewards of tougher management: Revenues, undermined by low prices for oil, slumped 9.4% at the 19 largest producers, but net income jumped 7.4%.

The cost-cutting successes were especially timely for the many companies whose primary products have not yet benefited much from the general economic recovery. Crude oil—saddled with lower prices; natural gas—with slumping demand; and steel—in a state approaching morbidity, fall distinctly into that category. And chemical results, though generally better than those of the basic materials, were mixed. Firms with concentrations in plastics, for example, did well, but those with fertilizer materials and agricultural chemicals suffered from the effects of the food glut and the PIK (payment-in-kind) program. Even where chemical sales and earnings were up healthily, most of the energy and diversified firms do not have a big enough stake in chemicals to turn around overall corporate results. The average (unweighted) percentage of sales accounted for by chemicals among diversified manufacturers is only 22%. Among the oil and gas companies, it is a scant 8%.

As a result, many chief executives are voluble about cost-cutting measures but somewhat muffled on the subject of sales in the current batch of earnings statements. Allied Corp. chairman Edward L. Hennessy Jr., for example, notes that his company chopped $687 million off total debt between last September and June 30, bringing its ratio of long-term debt to total capital (including Bendix on a pro forma basis) down from 37.7% in September to 28.7% at the end of the second quarter. Du Pont, reports chairman Edward G. Jefferson, lowered its debt ratio two points to 34% over the course of the first six months of the year.

When they can, chief executives also stress the impact of efficiency

Oil and gas, diversified manufacturing earnings rose moderately

		SECOND-QUARTER 1983						FIRST-HALF 1983					
	% chemical sales	Sales	Earnings	Change from 1982		Profit margin		Sales	Earnings	Change from 1982		Profit margin	
		($ millions)		Sales	Earnings	1983	1982	($ millions)		Sales	Earnings	1983	1982
OIL AND GAS COMPANIES													
American Petrofina	11%	$ 594.1	$ 8.6	−2%	−21%	1.5%	1.8%	$ 1,018.4	$ 8.9	−14%	−67%	0.9%	2.3%
Atlantic Richfield	8	6,523.2	393.4	−4	−4	6.0	6.0	12,842.4	723.8	−3	−9	5.6	6.0
El Paso	15	984.3	22.9	−6	26	2.3	1.7	2,207.1	37.1	5	−6	1.7	1.9
Exxon[a]	7	22,881.0	1075.0	−9	31	4.7	3.3	46,586.0	2135.0	−10	29	4.6	3.2
Getty Oil[b]	2	3,006.6	163.9	−3	5	5.5	5.1	6,025.5	321.7	−4	−4	5.3	5.4
Gulf Oil[c]	7	6,987.0	203.0	−6	25	2.9	2.2	13,885.0	356.0	−7	−10	2.6	2.6
Internorth[d]	8	1,058.1	37.5	47	50	3.5	3.5	2,417.9	139.4	12	5	5.8	6.2
Kerr-McGee[e]	13	835.5	37.8	−8	−25	4.5	5.5	1,686.1	61.5	−9	−36	3.7	5.2
Mobil	4	14,402.0	402.0	−9	40	2.8	1.8	28,690.0	652.0	−11	23	2.3	1.7
Occidental[f]	na	4,615.8	10.5	7	−84	0.2	1.5	9,505.8	36.4	12	−72	0.4	1.5
Phillips Petroleum[g]	15	3,790.0	137.0	−6	−6	3.6	3.6	7,430.0	266.0	−5	−9	3.6	3.7
Shell Oil[h]	17	4,872.0	390.0	−5	11	8.0	6.9	9,517.0	636.0	−4	−8	6.7	7.0
Standard Oil of California	3	7,092.0	368.0	−24	40	5.2	2.8	14,087.0	678.0	−27	38	4.8	2.5
Standard Oil (Ind.)[i]	9	7,400.0	426.0	−3	11	5.8	5.0	14,900.0	825.0	1	−3	5.5	5.8
Standard Oil (Ohio)[j]	4	3,101.0	476.0	−8	1	15.4	14.0	5,867.0	828.0	−16	−11	14.1	13.3
Sun Co.	3	3,780.0	135.0	−9	23	3.6	2.6	7,520.0	225.0	−8	−4	3.0	2.9
Tenneco[k]	7	3,566.0	205.0	−3	−12	5.8	6.3	7,175.0	315.0	−4	−13	4.4	4.8
Texaco	3	9,900.0	327.0	−14	7	3.3	2.7	20,100.0	646.0	−18	−4	3.2	2.7
Unocal	11	2,800.0	139.4	−4	−30	5.0	6.8	5,300.0	267.7	−2	−27	5.1	6.8
DIVERSIFIED MANUFACTURERS													
Aluminum Co. of America[l]	11	1,257.9	23.7	2	—	1.9	def	2,400.1	−5.3	−2	def	def	2.1
Allied[m]	23	2,621.0	106.0	−1	−5	4.0	4.2	5,189.0	224.0	−3	18	4.3	3.6
Beatrice Foods[n]	5	2,315.9	75.5	2	5	3.3	3.2	4,593.2	155.0	2	6	3.4	3.2
Borden[o]	30	1,084.0	45.7	4	43	4.2	3.1	2,021.4	68.3	3	39	3.4	2.5
Borg-Warner	19	881.1	45.0	4	−4	5.1	5.5	1,694.6	80.5	7	−3	4.8	5.3
Diamond-Shamrock[p]	31	978.4	26.3	14	−18	2.7	3.7	1,833.8	30.9	11	−49	1.6	3.7
Du Pont	33	8,854.0	271.0	5	10	3.1	2.9	17,451.0	474.0	4	−5	2.7	3.0
Eastman Kodak[q]	20	2,396.0	286.6	−1	−26	12.0	16.0	4,525.9	363.8	−3	−47	8.0	14.6
Engelhard	12	617.0	18.0	38	10	2.9	3.6	1,228.4	34.2	33	12	2.8	3.5
FMC	37	878.3	38.9	−3	−14	4.4	5.0	1,732.0	70.4	−1	−9	4.1	4.4
General Electric	4	6,720.0	521.0	1	12	7.8	7.0	12,820.0	946.0	1	12	7.4	6.7
Georgia-Pacific[r]	12	1,699.0	56.0	20	−21	3.3	5.0	3,118.0	86.0	19	−62	2.8	8.7
B. F. Goodrich[s]	37	798.6	4.2	1	−29	0.5	0.7	1,500.0	−3.6	0	def	def	def
Kaiser Aluminum	22	775.2	−51.3	−5	def	def	def	1,361.3	−80.1	−12	def	def	def
Koppers[t]	34	380.2	5.2	−9	−37	1.4	2.0	667.9	−7.6	−11	def	def	def
Eli Lilly	27	740.6	101.9	5	9	13.8	13.2	1,572.5	238.1	0	4	15.1	14.6
Merck	21	821.9	123.3	6	11	15.0	14.4	1,592.6	237.0	5	7	14.9	14.6
NL Industries[u]	33	346.7	−14.5	−43	def	def	11.8	718.1	−20.2	−43	def	def	13.1
Northwest Industries	22	501.3	1.8	−25	−98	0.4	11.4	920.5	3.2	−37	−98	0.4	11.7
Pfizer[v]	11	920.9	102.2	4	39	11.1	8.3	1,831.3	200.4	7	33	10.9	8.9
3M	15	1,779.0	169.0	6	6	9.5	9.4	3,482.0	326.0	4	5	9.4	9.3
Tyler[w]	35	229.9	5.3	4	56	2.3	1.5	442.0	6.0	3	76	1.4	0.8
Uniroyal[x]	31	545.8	19.6	1	142	3.6	1.5	996.3	23.2	−3	150	2.3	1.0
U.S. Steel[y]	6	4,400.0	−239.0	−14	def	def	def	8,260.0	−357.0	−18	def	def	def
Upjohn	17	519.2	44.0	9	15	8.5	8.1	1,003.3	89.5	7	10	8.9	8.7
Vulcan Materials	37	199.9	15.4	6	−18	7.7	10.0	354.5	15.3	1	−46	4.3	8.1

[a] Excludes nonrecurring charge of $106 million and gain of $136 million in second-quarter 1982. [b] Excludes nonrecurring charge of $250 million in second-quarter 1983. [c] Excludes nonrecurring gains totaling $20 million in second-quarter 1983, $49 million in first-half 1983, $65 million in second-quarter 1982, and $120 million in first-half 1982. [d] Excludes nonrecurring charges of $5.3 million in second-quarter 1983, $2.5 million in second-quarter 1982, and $4.2 million in first-half 1982. [e] Excludes nonrecurring charge of $17 million in first-half 1982. [f] Excludes nonrecurring gain of $141.1 million in second-quarter 1983 and charge of $8.6 million in first-half 1983; includes 1983 results of Cities Service Co. [g] Excludes nonrecurring gains totaling $32 million in second-quarter 1983 and $47 million in first-half 1982. [h] Excludes nonrecurring gain of $30 million in second-quarter 1982. [i] Excludes offsetting nonrecurring gain and charge in second-quarter 1983. [j] Excludes nonrecurring charge of $75 million in first-half 1983. [k] Excludes nonrecurring charge of $28 million in second-quarter 1982. [l] Excludes nonrecurring gain of $19.9 million in first-half 1982. [m] 1983 results reflect consolidation of Bendix and its ownership interest in Martin Marietta; pro forma data on a comparable basis for 1982 are used. [n] Results are for three months ending May 31 (first quarter of Beatrice Food's fiscal year 1984). [o] Excludes nonrecurring gains of $17 million in first-half 1983 and $38.3 million in first-half 1982. [p] Excludes nonrecurring gain of $3.3 million in second-quarter 1983. [q] Results are for periods ending June 12, 1983, and June 13, 1982. [r] Includes nonrecurring pretax gains of $28 million in first-half 1983 and $105 million in first-half 1982. [s] Excludes nonrecurring gains totaling $1.9 million in second-quarter 1983 and $13.5 million in second-quarter 1982. [t] Excludes nonrecurring gain of $5 million in second-quarter 1983. [u] Excludes nonrecurring charges totaling $86.1 million in second-quarter 1983. [v] Excludes nonrecurring gains of $4.4 million in second-quarter 1983, $8.7 million in first-half 1983, $7.8 million in second-quarter 1982, and $19.7 million in first-half 1982; 1982 results include results for Valleylab on a pro forma basis. [w] Excludes nonrecurring gain of $800,000 in first-half 1983. [x] Excludes nonrecurring gain of $18 million in first-half 1982. [y] Excludes nonrecurring gains totaling $127 million in second-quarter 1983 and $423 million in second-quarter 1982. def = deficit. na = not available.

Energy company petrochemical earnings are mixed

For oil and gas companies with chemical operations, depressed prices were as much a problem with their petrochemical products during the second quarter as with their primary energy materials. The difference was that sales volumes were up—in some cases substantially—in the companies' chemical units. As a result, about half of the 19 largest companies reported increased earnings from chemicals in the second period.

In fact, the aggregate results of eight producers reporting after-tax income from chemicals shows a 57% rise in net compared to second-quarter 1982. That total is more a barometer of a general turnaround than an accurate measure of overall improvement, however, since the bulk of the gain comes from two firms—Exxon, with an 89% increase, and Occidental Petroleum, which countered a large loss in 1982 with a small net this year. In addition, Getty Oil income rose, and perennially losing Gulf Oil recorded a smaller deficit than before.

Among companies reporting pretax chemical income, Atlantic Richfield recorded a $33 million operating income compared to a loss of $9 million in second-quarter 1982. And American Petrofina attributes a rise in income between the first and second quarters of 1983 primarily to a return to profitability in the petrochemicals and plastics segment.

The biggest loser remained Gulf. Chairman James E. Lee notes that although the company is seeing higher sales and production volumes for most petrochemical and plastics products, prices have not yet reached satisfactory levels. Mobil, which rebounded from a big first-quarter loss, returned chemical earnings still far below those of second-quarter 1982. The company briefly blames the decline on "weak market conditions." Standard Oil (Ind.), though recording a large decline from second-quarter 1982, comments with satisfaction on increases in sales volumes since late 1982.

El Paso, which is rumored to be trying to unload its chemical operation, says only that it lost as much on chemicals during the second quarter and first half of 1983 as it did during the comparable periods in 1982. At Unocal, parent of Union Oil of California, lower earnings from chemical operations contributed to a 30% decline in corporate income.

Still, the majority of the energy companies find hope in improvement between the first and the second quarters of this year. "While [chemical] industry overcapacity problems persist," remarks Shell Oil president John F. Bookout, whose firm reported a 17% decline in chemical earnings, "the combination of higher prices, stable feedstock costs, and rising volumes tied to renewed economic growth point to improving performance."

AFTER-TAX EARNINGS ON CHEMICALS

$ Millions	Second quarter 1983	Second quarter 1982	Second quarter % change	First half 1983	First half 1982	First half % change
Exxon	$53.0	$28.0	89%	$85.0	$ 55.0	55%
Getty Oil[a]	3.4	2.4	45	−30.1	19.0	def
Gulf Oil	−32.0	−36.0	def	−71.0	−112.0	def
Internorth	−1.8	0.9	def	−1.8	3.5	def
Mobil	7.0	13.0	−46	−7.0	26.0	def
Occidental	4.0	−12.5	—	20.8	−19.3	—
Shell Oil	5.0	6.0	−17	24.0	16.0	50
Standard Oil (Ind.)[b]	30.0	42.0	−29	34.0	83.0	−59

[a] Results are for Getty's refining, marketing, and chemicals operations. [b] Excludes nonrecurring $14 million gain in first-quarter 1982. **def** = deficit.

gains on earnings. Exxon Corp., for example, points out that the company's total operating, selling, and administrative expense in second-quarter 1983 was $400 million less than in 1982.

Still, only 12 of 26 diversified firms with chemical interests managed to raise earnings in the second quarter. The rest either had their net decline or recorded a deficit. The biggest gainers were Uniroyal, Tyler, Borden, and Pfizer. Stars on the debit side were Northwest Industries (owner of Velsicol Chemical), Koppers, B. F. Goodrich, Eastman Kodak, and Georgia-Pacific.

The performance of these companies' chemical operations was equally mixed. Agricultural glut and PIK blasted chemical income at Pfizer, sales of whose Treflan herbicide continued to wither, and at Northwest Industries' Velsicol, whose chemical and electrical operating earnings dropped 4%. Slumping caustic soda prices played the major role in bringing down chemical earnings at Vulcan Materials 80% and in FMC's industrial chemicals segment 6%. Even specialties were no talisman for success: "Specialty chemical and environmental products sales continued to be affected by depressed economic conditions worldwide and had a significant adverse impact on the company's results," comments Merck & Co.

At Du Pont, on the other hand, chemical and related earnings were up mightily—47%, compared to a corporate income jump of 10%. The company's after-tax income rose 329% for fibers, 206% for polymer products, and even 7% for agricultural and industrial chemicals. Allied chemical income rose 12%, and both Georgia-Pacific and Borden, with large polyvinyl chloride production, report substantial gains in chemical segment earnings.

What is perhaps most encouraging to companies weighing their performance over the half year and more since the official end of the recession is the pace, if not yet the size, of the recovery. A year-to-year comparison of the second quarters reveals the laudable 7.9% rise in earnings with its disappointing 0.7% rise in sales dollars. A comparison of second-quarter to first-quarter 1983, on the other hand, gives what may be a better gauge of the recovery's rate of acceleration: Among the 26 diversified firms, sales rose 7.9% and earnings a resounding 30.2%. That could be taken as an encouraging sign indeed. ☐

Some Canadian Chemical Firms Rebound

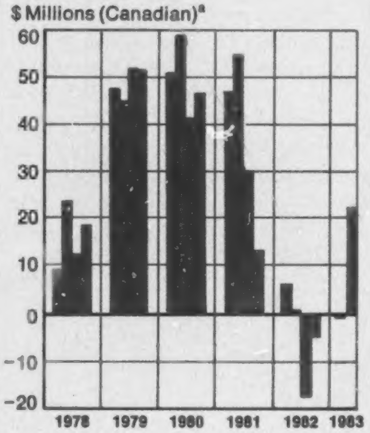
Better is preferable to worse. But it is not necessarily good. That's the situation that Canadian chemical companies find themselves in as they pass the year's half-way mark.

Canada's economy is on the mend and the country's beleaguered chemical companies are trying to get back into the black after last year's flood of red ink. Some are succeeding.

For most companies, second-quarter sales and earnings are much better than they were in the previous quarter. They also show a significant improvement over what they were a year ago. For the entire first half, however, the trend is not quite that clear-cut. Some companies are ahead of last year's pace in both sales and earnings. Others are not.

C-I-L Inc. is one that is not. Its second-quarter sales of $312 million (Canadian) are up only marginally over last year. Coupled with a poor first quarter, it has pushed company sales for the first six months down 3.2% compared to the first six months of 1982. Earnings are in the same boat. A good second quarter could not compensate for a poor first quarter and, as a result, C-I-L's earnings for the first half, at $13.9 million, are 16.8% lower than last year.

Profits return in second quarter



a After-tax earnings of four largest publicly reporting Canadian chemical companies—Celanese Canada, C-I-L, Du Pont Canada, and Union Carbide Canada.

C-I-L's problem is that some of its major markets haven't jumped on the recovery bandwagon yet. This is particularly true of mining and agriculture, which have crimped company sales of explosives, mining equipment, fertilizers, and agricultural chemicals. Sales of paints, plastics, and some specialty chemicals have been strong and have kept matters from being worse.

Union Carbide Canada, one of the hardest-hit Canadian chemical companies last year, still is in the red. Through the first six months, it has lost $9 million, compared to $5.7 million last year. Sales are down, too, for the first half, but chairman W. Norman Kissick believes that things will improve for Carbide Canada.

Celanese Canada, Du Pont Canada turn losses to profits

$ Millions (Canadian)	First-half 1983 Net sales	Change from 1982	Net income[a]	Change from 1982	Profit margin[b] 1983	Profit margin[b] 1982
C-I-L Inc.	$ 577.0	−3.2%	$13.9	−16.8%	2.4%	2.8%
Celanese Canada	193.4	24.2	3.7	c	1.9	def
Du Pont Canada	546.5	6.8	12.5	c	2.3	def
Union Carbide Canada	326.7	−8.4	−9.0	c,def	def	def
TOTAL	$1643.6	1.5%	$21.1	219.7%	1.3%	0.4%

a Net income from continuous operations, excluding extraordinary gains or losses. b Net income as percentage of sales. c Deficit in 1982. def = deficit.

Among the large, publicly reporting Canadian chemical companies, Celanese Canada and Du Pont Canada have done better than most in turning losses into profits. Celanese, for instance, lost $2.5 million during the first six months of 1982. This year, it recorded earnings of $3.7 million on much higher sales ($193 million).

Still, Ernest H. Drew, president and chief executive officer, is not completely satisfied. Although sales volumes continue to improve, product prices do not, he says. In addition, export sales remain spotty, particularly to the European Economic Community, where economic recovery has been slow and where the Canadian dollar remains strong against major European currencies.

So far this year, Du Pont Canada has come back strong. It has turned last year's first-half $1.9 million loss into $12.5 million worth of black ink this year. Sales are up about 7%, but this recovery has been uneven. Weaknesses in mining, energy, and heavy construction markets have kept sales of explosives, polyethylene pipe, and industrial fibers down. On the other hand, products moving into automotive, housing, and consumer durables markets are doing well.

Although Canadian chemical companies have staged a comeback as far as sales and earnings are concerned, it really is only a start. Earnings, for instance, remain well below prerecession levels. And these companies now must move into the third quarter knowing that these three months bring with them a seasonal business slowdown.

Still, Canada's chemical leaders are optimistic, if not exuberant, about the remainder of the year. There is still enough uncertainty about the country's energy policies and its attitude toward the petrochemical industry to warrant exuberance.

Earl Anderson, New York

Fiber intermediates struggle to recover

A Key Chemicals Review Page 10

AUGUST 22, 1983

CHEMICAL & ENGINEERING NEWS

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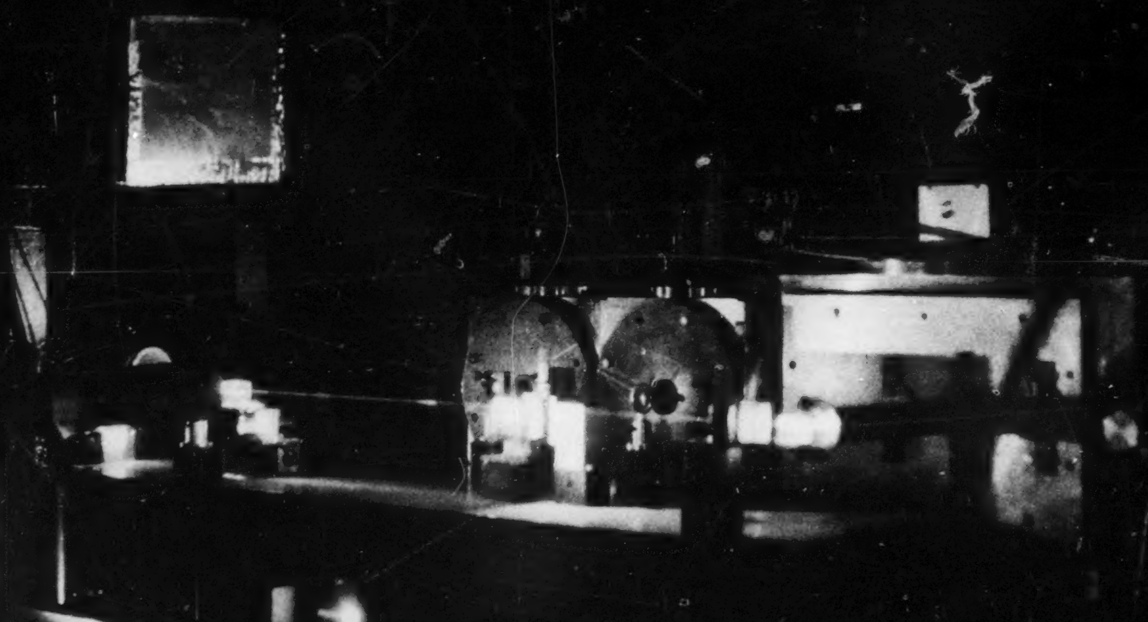

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METAL CLUSTERS

Pulsed-beam source offers new insights

Page 22

Cover: In supersonic molecular beam apparatus laser beam is deflected to where it vaporizes a nickel rod to produce the clusters to be studied. Photo courtesy of Richard E. Smalley, Rice University

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CHEMICAL & ENGINEERING
NEWS
AUGUST 22, 1983

News of the Week

- **Rise in bromine levels in Arctic air in spring measured; element may be linked to destruction of the stratospheric ozone layer.** Page 6
- **House subcommittee cites Defense Department for laxity in hazardous waste disposal.** Page 7
- **Coal scientist points up danger of drop in synfuels R&D funding brought on by current oil glut.** Page 7
- **Laser-based analysis system may shorten time needed to determine molten steel composition.** Page 7

Business

Fiber intermediates are not enjoying the general U.S. economic recovery; though synthetic fibers business improves, DMT/PTA, ethylene oxide, and cyclohexane gain little. Page 10

Government

Assessment of operations of the Defense Science Board leads to charges of failure to comply with law and policy directives and possible conflict of interest on part of members. Page 15

Administration policy on acid rain control is expected to come out of EPA report to be refined by cabinet council. Page 16

Education

Chemistry departments at several state universities have survived the economic crunch; California, Michigan schools cite healthy research support, academic strength. Page 34

The number of scientists and engineers employed at colleges and universities continues to grow, NSF reports. Page 36

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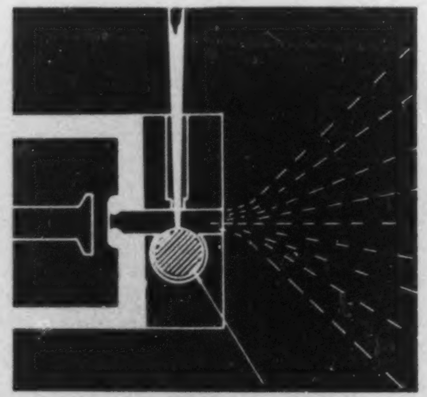


Science

Laser pulse that generates molecular beams of metal clusters simplifies spectra interpretation. Page 22

Fiber Intermediates Plod Through Slow Recovery

Despite much improved year in fibers demand, major intermediates—DMT/PTA, ethylene oxide, cyclohexane—still are struggling

Bruce F. Greek, C&EN Houston
William F. Fallwell, C&EN Washington

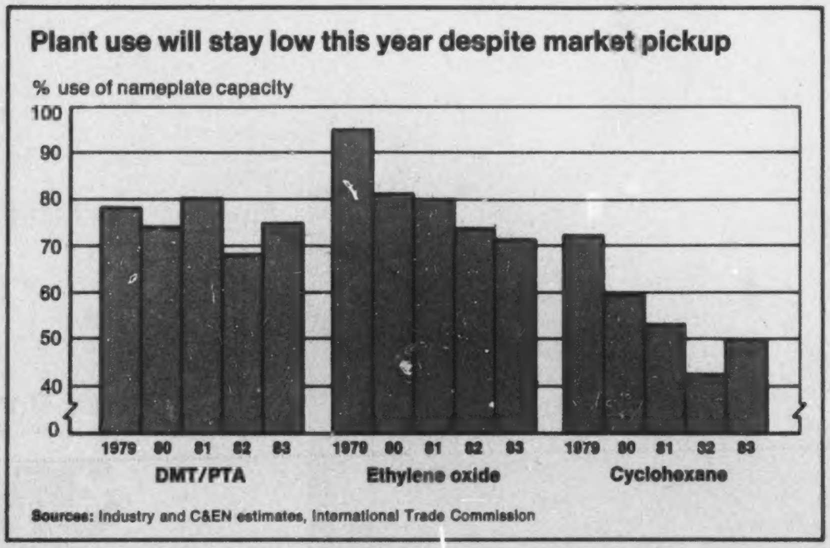
The remarkably strong general economic recovery in the U.S. this year still has left a few major chemical groups behind. The major intermediates going into synthetic fibers are one of these lagging groups. This may sound odd considering the greatly improved fibers business (C&EN, May 30, page 11), but for several basic reasons, it's true.

The three big-volume fiber intermediates whose immediate market prospects appear in the following pages—dimethyl terephthalate/purified terephthalic acid (DMT/PTA), ethylene oxide, and cyclohexane—trail the overall recovery pace for basic chemicals and won't make their producers very happy this year. In this respect, they don't correspond at all with the brightened outlook for the plastics intermediates, whose performance has jumped very much in tune with downstream polymers (C&EN, June 20, page 16).

Why don't the fiber intermediates also follow suit with their chief polymer uses? First, supply and demand in fiber intermediates is way out of line with the corresponding situation in fibers. The main reason is that the intermediates didn't go through nearly so wrenching a shakeout in plants and producers as did fibers after the mid-1970s. In fact, there were some capacity expansions. Intermediates producers are still stuck with yawning excess capacity. Several plants are shut down, but could in theory be restarted.

Key Chemicals

Plant use will stay low this year despite market pickup



Sources: Industry and C&EN estimates, International Trade Commission

Second, the foreign trade turnaround hurting chemicals in general has been extra hard on fiber intermediates. Although DMT/PTA haven't yet been nicked by imports, their exports are down more than two thirds since the late 1970s. For ethylene oxide, it's foreign trade in derivative ethylene glycol that is beginning to suffer. Glycol exports are expected to drop considerably in coming years after taking about 12% of production in 1982. Meanwhile, large glycol imports are feared for a net trade deficit. In cyclohexane, foreign trade was even more important in the late 1970s, taking about 18% of U.S. production. This year, more than three fourths of this export volume is gone, and what remains will take only about 5% of production.

Add it up, and the intermediates are well behind the recovery pace in fibers. For the three covered here, 1983 production will total about 12.6 billion lb, up 9% from 1982 but still down 5% from the 1979 record. Dollarwise, things are much worse. Total value of about $4.15 billion for the three intermediates this year is down fully 18% from the 1981 peak of $5.1 billion, even after an 11% pickup from 1982.

Plant capacity use remains low this year for all three chemicals, even dropping a bit for ethylene oxide. So there will be no major new capacity for quite a while. Severely depressed profit margins are beginning to move up, but producers are happy just to play catch-up in this business cycle. New investment will have to wait.

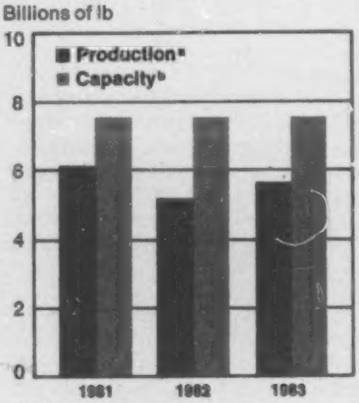
In short, fiber intermediates didn't pay the price that fibers did over the past decade. For this and other reasons, intermediates are not in a position to profit very much from even a strong general recovery.

Key Chemicals

DMT/PTA

- ***Demand recovering***
- ***Capacity holding***
- ***Prices firmer***

PRODUCTION/CAPACITY



a DMT plus DMT equivalents of PTA (1.0 lb of PTA = 1.17 lb of DMT). b First quarter.

HOW MADE

Oxidation of p-xylene and concurrent esterification with methanol to make DMT; oxidation of p-xylene to make PTA

MAJOR DERIVATIVES (U.S.)

Polyethylene terephthalate 90%, polybutylene terephthalate 5%

MAJOR END USES (U.S.)

Polyester fibers 70%, films 10%

FOREIGN TRADE

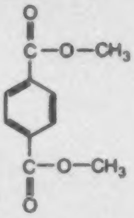
Exports—declining to below 100 million lb in 1983, imports—negligible

PRICES

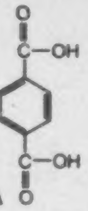
List prices about 35 cents per lb for DMT, 39 cents for PTA

COMMERCIAL VALUE

$2 billion for production, 1983



DMT



PTA

U.S. producers of dimethyl terephthalate (DMT) and purified terephthalic acid (PTA) are shaking off the effects of a very bad year in 1982. Their recovery is moving along but has quite a way to go. It will take well into 1984 for them to get back to record 1981 production levels, provided the general economic recovery doesn't stall out.

The improvement in demand this year for DMT and PTA has been under way since the second quarter, apparently gathering strength. This pickup, however, wasn't strong enough to give DMT/PTA a year-to-year gain in the first half. Even so, there has been a definite pickup compared to fourth-quarter 1982 and first-quarter 1983.

Assuming the demand improvement continues, upcoming monthly comparisons with 1982 could be spectacular. Although the recovery may slow toward the end of the year, it still may be enough for at least a 10% overall production gain in 1983 to 5.7 billion lb (with PTA converted to DMT equivalents at a 1:1.17 ratio). This would be up from 5.2 billion lb on the same basis in 1982.

Plant capacity for DMT and PTA totals a steady 7.6 billion lb per year. If 1983 production reaches 5.7 billion lb, the average plant operating rate will be 75% of the nameplate total. The last time the operating rate reached 80%—considered the threshold for good profitability in most chemicals—was in 1981. The 1983 operating rate then will not make the year anything special financially. It also will not precipitate any rush for capacity expansion. Such expansion is actually a few years off, since long-term growth in downstream polyesters was slowed drastically by the recent recession.

If the economic recovery continues in 1984, perhaps at a slower pace, production of DMT/PTA will continue to rise at a rate above the long-term forecast. It might be up 7 to 8% over 1983 to outstrip the peak 6.1 billion lb of 1981.

At the same time, the market pattern is changing. Exports of DMT/PTA have declined in recent years, partly because of the worldwide recession but also trade restrictions. Unless the recent textile trade pact with China (C&EN, Aug. 8, page 4) spurs demand for exports of DMT/PTA derivatives, largely polyester staple, U.S. markets will have to absorb declining DMT/PTA exports.

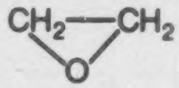
The U.S. market mix also is changing as fast-growing bottle resins made from DMT/PTA take an ever larger slice. In 1983, polyester bottle resins are not expected to increase this share very much because polyester fiber demand also is doing well. However, future potential growth for polyester resins in bottles remains large, especially if technical problems such as poor shelf life and hot-fill capability are solved. Although these problems could take some time to overcome, others such as competitive cost-performance for half-liter soft-drink bottles could be handled much faster, perhaps as early as this year. This development and other small new uses could push the bottle outlet for DMT/PTA above 10% of the total in 1984.

Hence, bottle resins could be the boost that DMT/PTA need to regain plant use and profitability levels to spark new investment. Bottle resin producers and consultants are extremely optimistic about market growth this decade, citing the small soft-drink bottle as the immediate target. Longer term, it's the untapped beer-bottle market that has resin makers most excited. To crack this area will require improvements in resins, but producers think they may have the grades they need by the late 1980s.

Well-established polyester fiber demand accounts for almost 70% of U.S. use of DMT/PTA. After slipping in the severe recession of 1982, this use is back up again but probably will go into a long, slow decline in its share of the total production, since fiber volume will not rise nearly so fast as will bottles or film. Specifically, longer-term growth rates for fibers are forecast to be about 3% a year, compared to 6 to 12% for film and bottles. Of course, as with all fibers, forecasts are subject to drastic changes because of fashion changes in the apparel market.

On balance, 1983 is a year rewarding the hard-pressed staying power of DMT/PTA producers. If the recovery continues in 1984, producers will get further dividends for not rushing capacity expansion plans in the early 1980s. Even so, DMT/PTA will not be one of the better basic chemical businesses this year.

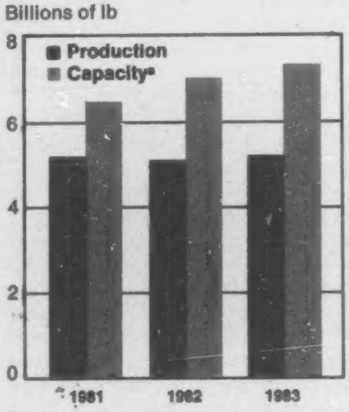
Key Chemicals



Ethylene Oxide

- ***Demand up slightly***
- ***Supply growing***
- ***Prices still weak***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Vapor-phase oxidation of ethylene with oxygen or air

MAJOR DERIVATIVES (U.S.)

Ethylene glycol 60%, ethoxylates 10%, glycol ethers 10%

MAJOR END USES (U.S.)

Polyester fibers, films, and resins 30%; antifreeze 25%; surfactants 10%; solvents 5%

FOREIGN TRADE

Exports—probably below 10 million lb in 1983, imports—below 50 million lb

PRICES

List price 45 cents per lb

COMMERCIAL VALUE

$1.75 billion for production, 1983

Ethylene oxide's strange holding pattern is heading through its sixth year in 1983. Once again, production is fluctuating a bit over 5 billion lb, and producers have the same old fight with profitability. In other words, for this product a good year in the economy isn't much different from a bad year.

Production in 1983 is climbing perhaps 2% from 1982 to about 5.2 billion lb, partly because of capacity additions that force more product inventory. It will take a lot longer before production again reaches the record 5.7 billion lb of 1979. An eventual new record is widely forecast but is clouded by a loss of derivatives exports, mainly in ethylene glycol, and a companion rise looming in derivatives imports.

Oddly, plant capacity in ethylene oxide continues to rise. In 1983, the latest round of expansions will be completed with a unique plant transported from Puerto Rico to Beaumont, Tex. This unit, a joint venture of PPG Industries and Du Pont, has been missing from C&EN's capacity totals since the turmoil in Puerto Rican chemicals in the late 1970s.

Further new capacity isn't even in the discussion stage because of the likelihood of net imports of ethylene oxide derivatives later in the 1980s. Older, currently shut-down capacity also is considered unlikely to restart. Overall, nameplate capacity of 7.3 billion lb per year at the beginning of 1983 (not all of it operating) will increase 4% during the year. As usual, there also will be some small debottlenecking increases undetected in the official totals.

Since the new Texas plant will come on late in the year, existing capacity will run at an average of 70 to 75% of nameplate capacity to meet the production forecast for 1983. Unfortunately, this rate is even lower than in 1982, contrary to the rising trend in most big-volume chemicals.

Most ethylene oxide production continues to be consumed at the plant site, chiefly in ethylene glycol, which takes nearly two thirds of it. Other captive outlets are ethoxylates, ethers, and amines. Merchant U.S. sales of ethylene oxide run less than 10% of production. Foreign trade in ethylene oxide itself also is very small.

Derivatives sales are therefore the main engine in ethylene oxide trends. Ethylene glycol goes largely to polyesters for subsequent use in fiber, film, and bottles. Antifreeze is the next largest glycol outlet.

Glycol uses presented a diverse picture in early 1983. Polyester demand was relatively strong because of a significant improvement in the fibers market plus continuing strong growth in bottle resins. Now, however, according to some industry analysts, the big rise in overall demand for polyester is over, although demand continues to stay high for fibers. Bottle demand is expected now to rise more slowly, with seasonal variations in the soft-drink market. Longer term, as with DMT/PTA, bottles may give ethylene oxide a major pickup as markets open up in small soft-drink containers and, much later, in beer bottles.

Antifreeze, which makes up about a quarter of U.S. demand for ethylene oxide, is entering its critical time of year. Most antifreeze bottling has peaked, and movement into distribution channels is well under way. Antifreeze producers are hopeful that an inventory runup in 1982 due to the recession will not be repeated. This excess inventory finally was worked off in the first and second quarters of 1983. With their real-dollar income generally up, consumers have less incentive for squeezing another year from their cars' antifreeze, so antifreeze demand may be up modestly this fall. Even so, with more and more small cars and small radiators on the road, the outlook for growth in antifreeze demand for ethylene oxide remains low, perhaps 2% per year on average.

Exports of ethylene glycol have been large, about 500 million lb last year. This market could diminish soon as Canadian producers move in aggressively with product made from lower-cost feedstocks. A dent in exports would rob glycol of one of its best growth areas over the past half decade. Since 1978, glycol exports mushroomed more than threefold by 1982.

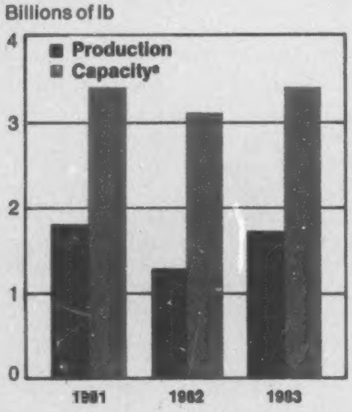
Demand will increase for other smaller uses of ethylene oxide in 1983 and 1984, but none are large enough to do much for total ethylene oxide demand. Hence, ethylene oxide will be riding as usual with ethylene glycol—not the happiest of prospects.

Key Chemicals

Cyclohexane

- ***Demand back up***
- ***Capacity up***
- ***Prices rising***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Catalytic hydrogenation of benzene; recovery from natural gasoline

MAJOR DERIVATIVES (U.S.)

Adipic acid 60%, caprolactam 30%

MAJOR END USES (U.S.)

Nylon 66 60%, nylon 6 30%

FOREIGN TRADE

Exports—declining to possibly below 100 million lb in 1983, imports—negligible

PRICES

List price $1.64 per gal; discounting general

COMMERCIAL VALUE

$400 million for production, 1983

Cyclohexane is tied firmly to derivative nylon and has to ride with its ups and downs. In end-market terms, because nylon's biggest use is in carpets, cyclohexane really depends on the big-ticket consumer durables side of the economy, especially new housing.

That's not bad in 1983, since housing has enjoyed a big upswing. With some lag due to product pipeline filling, cyclohexane indeed has felt the surge downstream. Production is expected to be up nearly one third this year to 1.7 billion lb after tumbling nearly one half from its peak of 2.4 billion lb in 1979. Cyclohexane's performance in the previous three years was one of the worst in the whole chemical industry because of the general shellacking in nylon markets. However, cyclohexane's upturn this year and next could be one of the strongest, since nylon is in a robust recovery.

An important reason cyclohexane has such gyrations is that it no longer has a big swing market in exports. Once 18% of production, exports are now down to about 5%.

An important influence in cyclohexane's rebound is inventory building throughout its product chain. But one industry analyst says that inventory building in carpet nylon is about over, since suppliers have a clearer idea now of the year's carpet demand in new and resale houses. Beginning this quarter, carpet fiber production will follow more closely actual sales, and inventory building will become relatively minor, increasing only in line with carpet sales. This would mean that cyclohexane demand still will go up through the rest of 1983, but not at the former fast rate.

If growth does hold up through 1983, cyclohexane production would nearly make it back to the 1981 level. One subtle factor in the output rise, analysts suspect, is that the official government data may be slowly catching up with previously unreported production. This would mean that official production figures over the years for cyclohexane have been biased low. Such a variance partly explains the product's extraordinarily low apparent capacity use of recent years.

Plant capacity for cyclohexane also will continue shifting. In 1981, Commonwealth Oil's plant in Puerto Rico was shut down permanently, cutting about 300 million lb per year from total capacity. Then earlier this year, Du Pont added a bit more than 300 million lb a year of capacity, returning the nameplate total to about 3.4 billion lb per year.

If cyclohexane reaches forecast production in 1983, nameplate (but not necessarily operating) capacity will run at an average rate of only 50%. However, since at least 400 million lb of capacity is shut down, operating capacity is going at a rate of at least 57%.

This rate suggests that still more capacity might be ripe for shutdown, industry analysts say. Actual scrappage, however, is thought to be a long time off. These plants apparently suffer relatively little from being shut, much like other plants that process hydrocarbons without using corrosive inorganics such as chlorine. Hence, plants on standby will continue to lead to a low average plant operating rate for some years ahead.

On the market side, cyclohexane's price depends directly on the price of raw-material benzene, with a few cents extra thrown in for process and hydrogen costs. Cyclohexane and benzene prices tend to move in tandem, which at the moment means very slowly up.

However, the hydrogen cost factor is becoming much more important for the next few years, if not for a decade or more. Hydrogen has grown more valuable to oil refiners as they move more heavily into hydrodesulfurizing their higher sulfur-content crude oils. As a result, by-product refinery hydrogen, once generally burned as cheap fuel, now has much more highly rated things to do. As yet, the cyclohexane price doesn't reflect the full rise in hydrogen values.

Given the paltry profitability afforded by cyclohexane's current price and the product's huge excess capacity, new investment is unlikely except in special situations. Du Pont's new plant is such a case, built because of the company's large internal needs for cyclohexane and the presence of a large by-product hydrogen supply from nearby chlorine units. So despite this particular project, cyclohexane remains in poor financial shape and can't do much better for a long time.

SEPTEMBER 5, 1983

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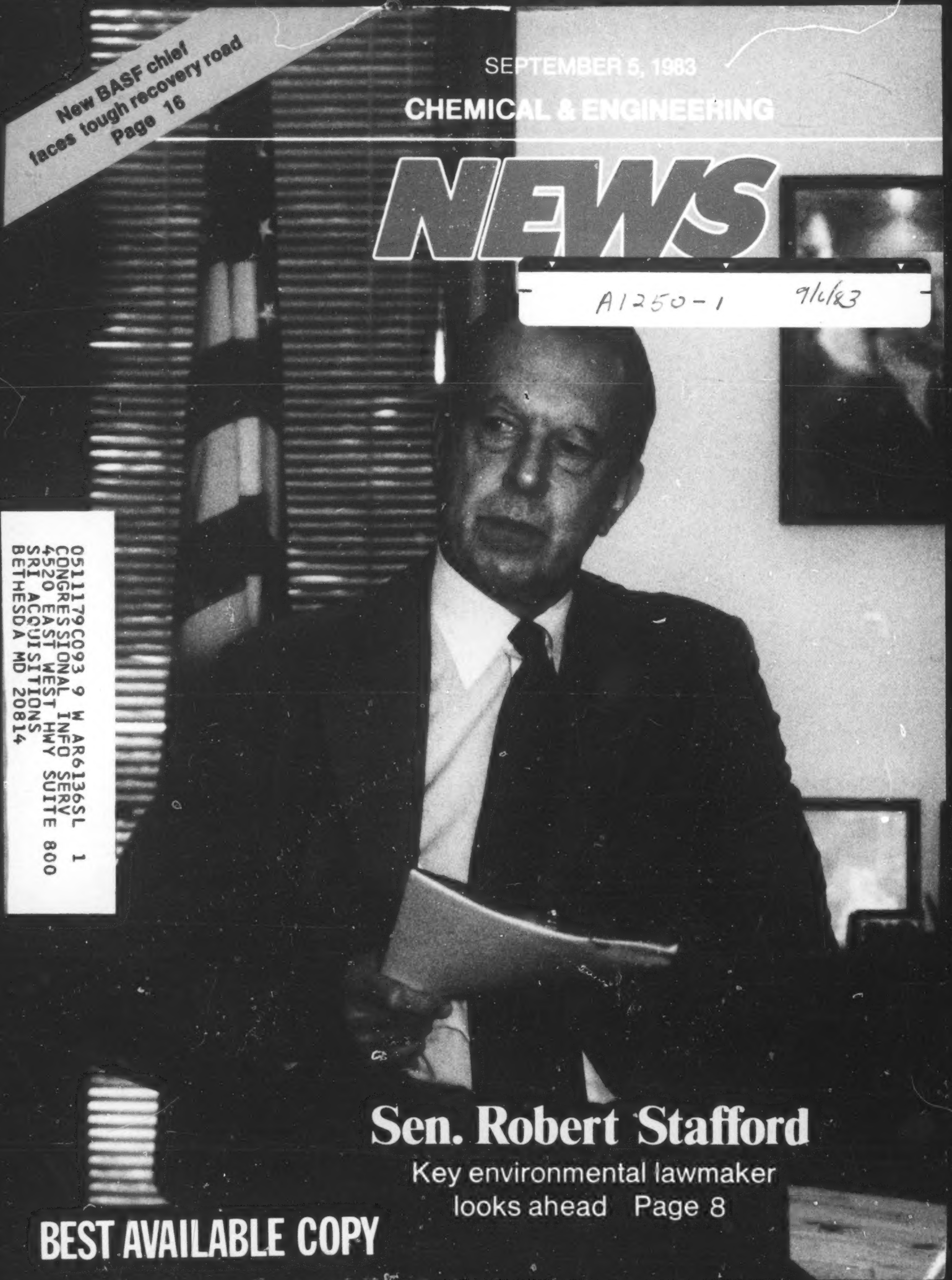

New BASF chief faces tough recovery road Page 16

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Sen. Robert Stafford

Key environmental lawmaker looks ahead Page 8

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Cover: Photo by C&EN's David J. Hanson

CHEMICAL & ENGINEERING NEWS

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SEPTEMBER 5, 1983

News of the Week

- **Biological chemicals on young Earth, health effects of service in Vietnam among scientific news from ACS national meeting.** **Page 4**
- **ACS annual meeting draws 13,000; more than 3500 technical papers presented.** **Page 5**
- **Research on enzyme inhibitors may lead to better drugs for diabetics.** **Page 5**
- **Events of ACS annual meeting in Washington, D.C., as seen by a photographer.** **Page 6**
- **EPA survey shows previous estimates of hazardous wastes generated in U.S. were much below actual levels.** **Page 7**
- **El Paso Products Co. will cut its chemicals workforce 25%.** **Page 7**

Business

Chemical industry executives turn to small computers, specialized computer firms for quick, inexpensive access to data. **Page 14**

International

Hans Albers, new chairman of West Germany's BASF, discusses plans to keep the firm competitive, take on new ventures. **Page 19**

Government

EPA drafts plan of attack on dioxin—to determine the extent of its contamination, begin cleanup and preventive programs. **Page 21**

Science

Reports from the ACS national meeting on selectivity of poisoned hydrogenation catalysts, unusual photochemical reaction that may find many uses, advances in polymer surface chemistry. **Page 24**

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Computer Services Evolving For Chemical Managers

Advent of the small computer reduces the need for time-sharing, alters the mix of computer services bought by chemical firms

David Webber, C&EN New York

Not very long ago at all, the computer meant just one thing: the mainframe—the massive data processing unit that ushered in the computer age. But even as mainframes grew larger and more powerful, computer evolution branched off into a line of small processors—minicomputers, personal computers, and home computers. As the capabilities of the smaller units expanded, experts began to predict the eventual demise of the mainframe, seeing the aboriginal form as a sort of oversized dinosaur in a new era belonging to the compact. Small computers, some said, would crunch numbers as well as the dinosaurs did, occupying a mere desktop instead of an entire climate-controlled room while they were doing it.

For chemical industry executives working in market research, financial planning, and other managerial positions, the burgeoning of the small computer has indeed increased both speed—as the need to queue up for time on the corporate mainframe is reduced—and control—as the ability to manipulate data on the desktop processor expands. At the same time, however, the mainframe, with its far greater capacity, has not disappeared. Nor do the most recent studies any longer forecast its extinction. What is occurring instead is a shift in the mix of computer-related services that executives can purchase from outside vendors—a shift that companies think will more efficiently exploit the most advantageous aspects of the great capacity of the mainframe and the intimacy of the small computer.

For a long time, chemical market researchers and financial planners have been able to draw on the resources of outside computer service firms for a multitude of services. These include access to numerical databases: files of statistics on production, capacity, imports, exports, and the like, to "supermarket" information services like Lockheed's DIALOG and SDC ORBIT, and to specialized data banks like those operated by the *New York Times* (soon to be removed from public access), Dow-Jones Co., patent databases, health and environmental data-bases, various government databases, and others.

Up until now, if a chemical manager wanted to generate market or financial forecasts, he or she could pull data from these sources and, using an in-house mainframe computer, run "what if" calculations on a spreadsheet program. But this system had its drawbacks: It could take lots of time and, often, the complex work could be performed better by a computer firm specializing in the chemical industry, which had highly involved models for just that purpose already prepared.

On the other hand, having an outside firm do all the calculations, rather than just the extremely complex ones for which it was best suited, could get very expensive. In budget-conscious times, the specter of high time charges for computer use could be inhibiting to an executive who, with just a few more calculations, might reach an important conclusion.

Now, computer service firms that specialize in the chemical industry—such as Data Resources Inc. (DRI) of Lexington, Mass., Sage Data Inc. of Princeton, N.J., and Chase Econometrics of Bala Cynwyd, Pa.—are finding that as the processing sophistication of their customers rises, the relative importance of time-sharing—the traditional computer service, in which the use of a firm's databases and data processing is billed on a fee-per-minute basis—is shrinking. The dynamic of the business has shifted, instead, to programs and customized services that make it possible for customers to use computers more cheaply, with greater flexibility, and with less re-

Computer services boom to continue, but more slowly

					Annual growth, %		
$ Millions	1967	1981	1985[a]	1995[a]	1967–81	1981–85[a]	1985–95[a]
Computer services	**$1010**	**$18,660**	**$36,600**	**$100,000**	**23.2%**	**18.3%**	**10.6%**
Processing services	720	9,140	15,400	33,000	19.9	13.9	7.9
Professional services	65	3,640	7,900	25,000	33.3	21.4	12.2
Packaged software	210	3,920	8,200	23,000	23.2	20.3	10.9
Turnkey systems	15	1,960	5,100	19,000	41.6	27.0	14.1
Computer shipments	**5530**	**15,200**	**24,700**	**40,300**	**7.5**	**12.9**	**5.0**

a Forecast. Source: Predicasts

liance on both external and in-house staff support.

"In a sense, the time-sharing side of the business is declining because of the onrush of minicomputers, superminicomputers, and PCs [personal computers]," says Ronald M. Whitfield, DRI's vice president, chemicals practice. "What is growing now is specialized software."

The reason is the increasing demand for speedy, flexible ways to transfer or "download" data from a mainframe to a small computer. Until fairly recently, programs that could transfer data and enable customers to create, for instance, business graphics other than in an on-line (pay-by-the-minute) mode were scarce. Now this software, such as DRI's DRILink and Sage's SAGEPC, can link the big data processing capacity of the database company's mainframes with the spreadsheet and graphing abilities of the customer's small computer.

"It's almost the perfect situation for the consumer," comments DRI's Whitfield. "You can look at the menu of items you need to do—say, forecasting and analysis—and you can do a little on DRI's mainframe, then download to your own mini or PC. Then you can access as well to your in-house mainframe for internal information."

"What's also coming on strong is microplotting," says Peter P. Pranis Jr., senior consultant at Probe Economics, Mt. Kisco, N.Y., the chemical industry forecasting and consulting arm of Sage Data. "Say you want to run multiple plots for a business graph. You run mainframe information from, say, Sage, into your PC and put it on a disk, then add it to your plotter."

The result is a graph built on the huge data processing capacity of the mainframe, but generated in the customer's personal computer, which would have neither enough capacity nor in most cases sophisticated enough modeling equations alone to perform the complex calculations done in the outside firm's mainframe. The data can be manipulated by the chemical manager personally without the pressure of mounting on-line charges.

This shift in the relationship between the mainframe and the small computer comes at a time when demand for U.S. computer services is expected to grow fivefold between now and the mid-1990s, according to a study published earlier this year by Predicasts Inc., the Cleveland-based business information and market research house. According to Predicasts, there will be a substantial alteration in market share among the various categories of computer services, which, as a whole, will grow much faster than computer equipment shipments.

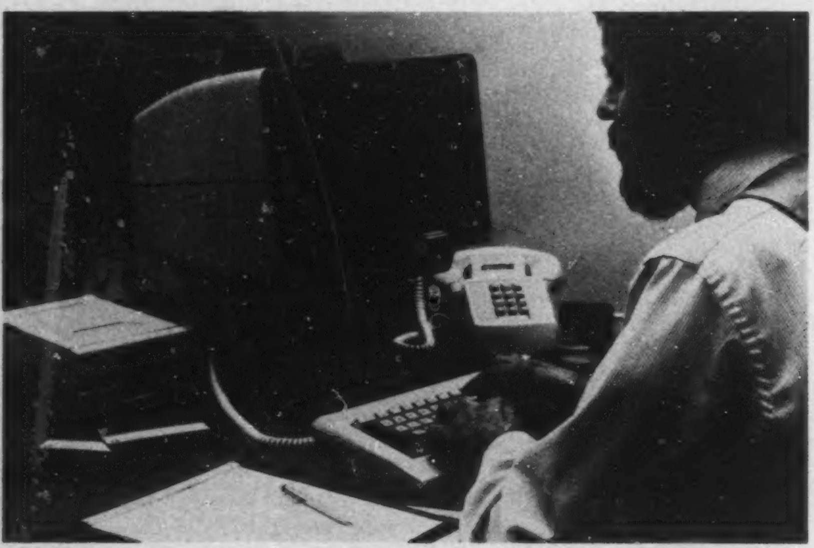
Data processing, whose main business outlet is time-sharing, will continue to dominate the service industry, its revenues climbing at a 13.9% annual rate between 1981 and 1985 to $15.4 billion. During the same period, however, professional services—assistance in more complex processing operations—will boom. Growth will amount to more than 21% per year, reaching $8.2 billion in 1985. The other, somewhat smaller, service areas—packaged software and turnkey systems—also will grow rapidly, at annual rates of 20.3% and 27.0% between 1981 and 1985, respectively.

As a result, the share of the market held by data processing will shrink from 71% in 1981 to 42% in 1985. By 1995, Predicasts says, the reconfiguration of market share will be even more pronounced: Data processing revenues will account for just 33% of the service segment, whereas professional services' share will have risen to 25%, packaged software's to 23%, and turnkey systems' to 19% of an overall $100 billion business.

Computer service companies are scrambling now to adjust to the changes as they occur. As time-sharing declines in relative importance, service firms will beef up their software development and professional services operations. Consulting in the form of data analysis and forecasting, already integral aspects of the business, will become even more important and more service oriented.

"As far as the forecasting business goes," comments DRI's Whitfield, "customers will still prefer us to do it for them, but they will want us to make it easier for them to understand. They will want more 'what ifs', more ranges in the forecasts."

On the plus side, the new interface software makes it possible for small companies, which could not afford to use on-line services, to link up with the computer service companies. "We're getting calls now from companies that couldn't use us before, but now we're breaking data down into such small chunks, a little plastics manufacturer could use us," points out Whitfield. "We are now coming across on the kind of little machine it can afford to buy." □



With personal computers such as Cromemco's new C-10 desktop unit, executives can tap into the processing power of the mainframes

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NEWS

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Their views and backgrounds
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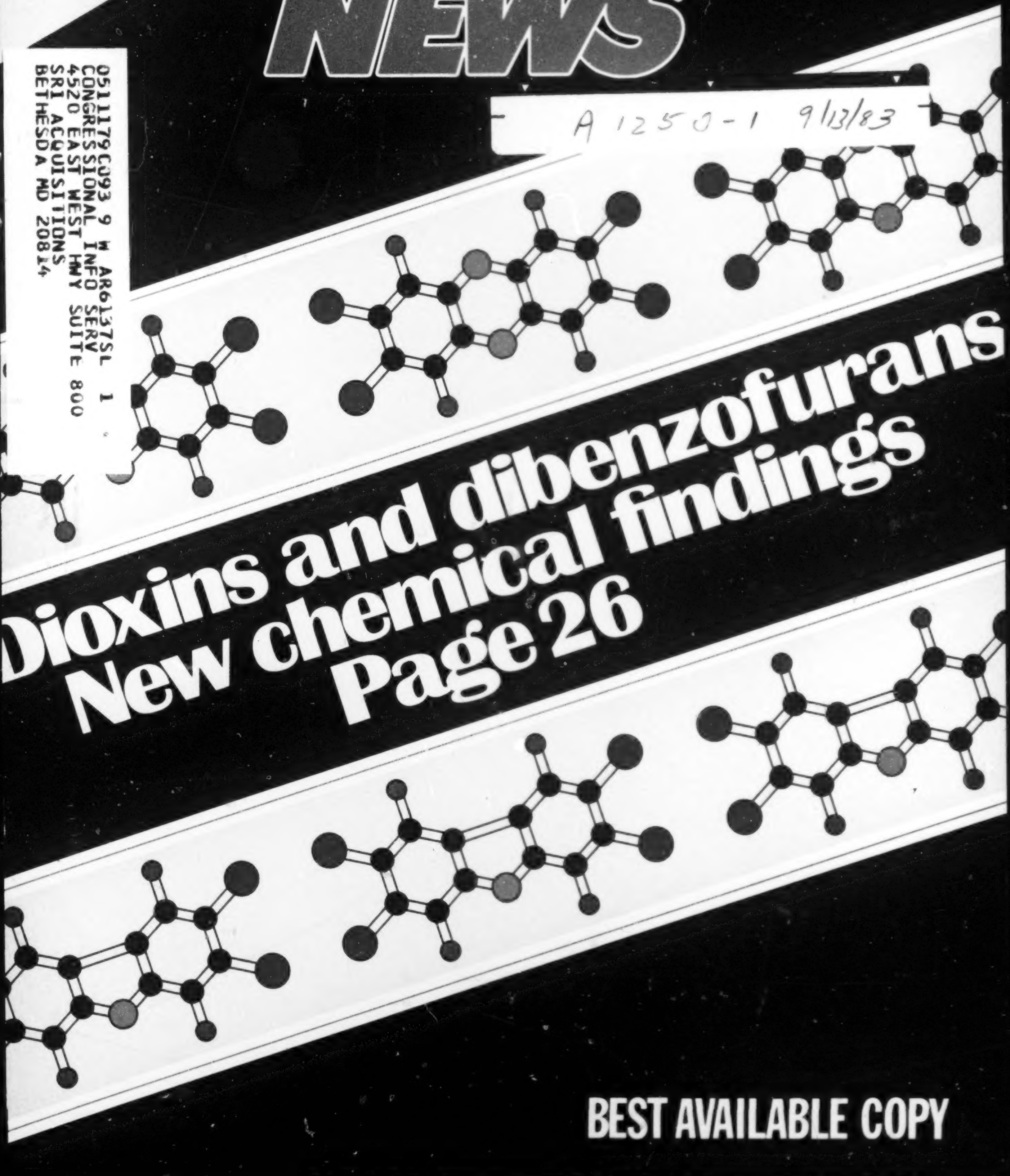

Dioxins and dibenzofurans
New chemical findings
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News of the Week

- **Economists predict the recovery will proceed steadily, auguring well for chemicals.** Page 6
- **House bloc opposing binary chemical weapons production may stall Defense funding.** Page 7
- **Science academies of the U.K., Norway, and Sweden set up acid rain research study.** Page 7

Business

Chlor-alkali makers face continued overcapacity, low growth, thus permionic membrane technology will be used sparingly. **Page 9**

International

Enzymes business has lured some large chemical, biotechnology firms; U.S. chemical trade surplus expected to continue. **Page 11**

Government

Symposium discusses successes, failures of patent law changes; another probes federal agencies' use of risk assessment. **Page 22**

Science

From the ACS meeting: survey on public perceptions of science; good look at surface chemistry; computers and carbenes. **Page 28**

Education

Holistic approach to teaching analytical chemistry would stress the problem as well as the sample, educator says. **Page 37**

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Also from the meeting: charm of microemulsions; optimizing use of energy; new kinds of catalysts; supercritical extraction. **Page 41**

ACS Election

Candidates for 1984 ACS president-elect, regional directors, and director-at-large present their platforms. **Page 54**

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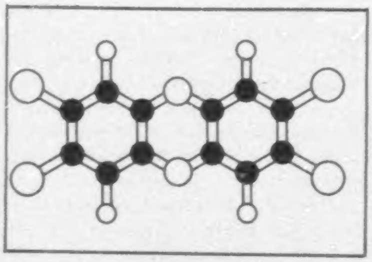


Cover Story

Several studies carried out to determine health effects of dioxins and dibenzofurans reported at meeting. Page 26

Chlor-Alkali Companies Plagued by Low-Growth Outlook

Many firms can't fund needed investments because of poor profits, but will use newer membrane technology for incremental plant expansions

Washington, D.C.

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Hard-pressed chlor-alkali companies, reeling from such body blows as overcapacity, low operating rates, a poor profit picture, and low growth projections, will have problems generating enough earnings to fund the investments that will be needed in the future.

Technology will play a key role in their efforts, Paul J. Kienholz, chlor-alkalies business manager for PPG Industries, told the Chemical Marketing & Economics Division. But he doesn't see a significant trend toward using the new and highly touted permionic membrane technology in new, small captive plants in the U.S. Instead, he thinks that some of the lean and mean companies that survive in the chlor-alkali business will use membrane cells for incremental expansions that would more closely match growth in demand.

Kienholz says that this type of installation does not require the typically large replacement costs. "It will be easier to justify," he says, "and this is where I believe that membrane technology will be used most effectively."

Justifying any investment right now is difficult for chlor-alkali companies. Profits are down, and with low growth rates and low operating rates ahead, the future isn't especially encouraging.

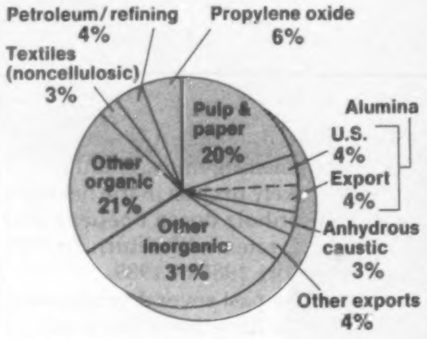
Throughout the 1950s and 1960s, chlorine growth rates of 7 to 9% annually were common. In the 1970s, 2%-per-year rates were typical. At one time, the ratio of chlorine growth to GNP growth was 2.6; in the seventies, it was more like 0.5.

What stunted chlorine's growth, Kienholz says, was a variety of environmental and toxicological developments, as well as some changes in processes that consume chlorine. Several economic recessions didn't help.

Over the next 10 years, Kienholz estimates that chlorine demand will increase at a 2.7%-per-year average clip. The first half of the decade will be stronger—about 3% per year—but this will dip slightly to about 2.5% annually between 1987 and 1992.

For the 1.1 tons of caustic soda that is coproduced with chlorine, future growth rates are in the same ball park. Over the next 10 years, Kienholz has caustic demand growing an average 3% per year, again stronger in the first five years than in the last five.

Caustic soda has diverse markets



Total 1982 use = 9.2 million tons

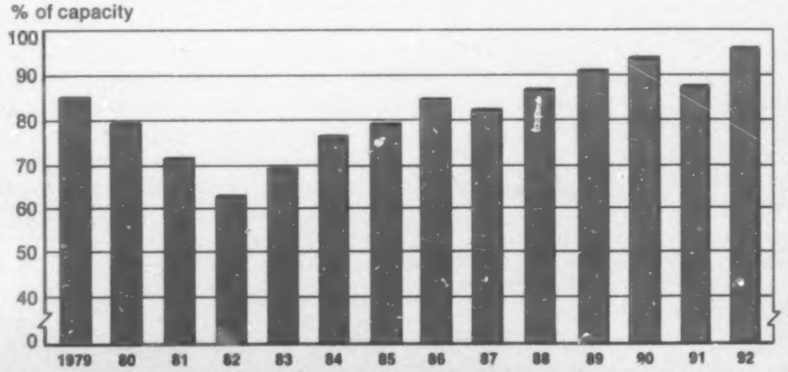
Source: PPG Industries

At those rates, companies should be able to manage chlorine-caustic imbalances easily, says Kienholz. The traditional route is to replace caustic with lime and soda ash.

A more serious problem, however, is plant operating rates. Historically, the chlor-alkali industry often has run at 95% of capacity or better.

Since the 1975 recession, however, operating rates below 80% have been

Chlorine operating rates: no 90% of capacity until late 1980s



Note: 1983 and on are forecasts. Source: PPG Industries

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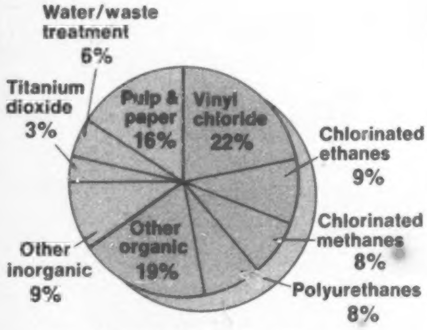
Vinyl chloride is big chlorine user



Total 1982 use = 9.2 million tons

Source: PPG Industries

the rule rather than the exception. Even after taking into account plants that are likely to close in the next five years, Kienholz doesn't believe that operating rates will return to 90% levels before 1988 or 1989.

Over the past several years, plant shutdowns have been the order of the day. Between 1970 and 1981, about 15 plants, with more than 3000 tons per day of chlorine capacity, were shut down permanently. The 1981–82 recession has had a brutal impact on the industry. Last year alone, plants with more than 2800 tons per day of capacity were closed, either permanently or temporarily.

Kienholz believes that, over the next few years, an additional 4200 tons per day will be shuttered. All of this adds up to a loss of more than 10,000 tons per day for an industry whose capacity has ranged from 28,000 to 40,000 tons daily.

U.S. chlorine plant shutdowns will continue

	Capacity (tons per day)
1970–81	
Various[a]	3,125[a]
1982	
Dow Chemical, Midland, Mich.	800[b]
Occidental, Taft, La.	685[b]
Montague, Mich.	225[b]
LCP, Linden, N.J.	425[b]
Olin, McIntosh, Ala.	350[b]
Pennwalt, Calvert City, Ky.	330[a]
Champion International, Pasadena, Tex.	60[a]
1983 and beyond	
PPG Industries, Barberton, Ohio	340[a]
BASF Wyandotte, Geismar, La.	820
Various potentials	2,890
TOTAL	10,050

a Permanent shutdown. b Temporary shutdown. Source: PPG Industries

As a result, Kienholz says that the industry is entering "an unprecedented era" in which low growth in capacity will occur over longer periods of time than ever before. The survivors, he says, will be those who are cost-competitive. This means being efficient with energy, capital, and people.

Another key will be large plants that provide economies of scale, he says. New plants will not be in the picture. For the most part, smaller incremental expansions using membrane cells at existing units will be the norm. Environmental concerns and power requirements rule out mercury cells.

Permionic membrane technology is advancing swiftly, so swiftly that a legitimate concern is that a plant may be outdated a few years after it comes on stream. But there is one overriding factor influencing the choice and use of technology in U.S. chlor-alkali plants, Kienholz says. Today, more than 75% of U.S. chlorine capacity remains in diaphragm cells. Much of this capacity is in large-scale plants that have been modernized in the past five years and are extremely energy-efficient. Equally important, these plants were built at capital costs that can't be approached today.

In addition, many of these units have highly efficient power sources in their own combined-cycle gas turbine investments. For economic reasons, Kienholz says, they would be difficult to idle.

Factors such as these put a limit on how new chlor-alkali technology can be used in the U.S. Kienholz thinks that by the end of the decade diaphragm cell units still will account for a large share of total capacity.

There also is the demand outlook to consider. Although he sticks by his 2.5%-per-year estimate, Kienholz says that a 1.3% rate is not out of the question. That's what it has been since 1968. "How many of us will be willing to invest in a business that offers only between 1- and 3%-per-year growth rates based on uncertain assumptions?" he asks. In addition, prototype membrane cells that have been operating for more than a year have pushed energy requirements down another 30%. It is difficult to justify building a completely new membrane unit based on today's technology, says Kienholz, when that technology could require 35 to 40% more energy than a technology that might be just around the corner.

Where does this leave the companies that might survive in the chlor-alkali business? In an excellent position, Kienholz says, because they can take optimum advantage of these developments with minimum risk.

Many major producers with large plants generate their own power. Some have their own cogeneration systems; others are considering them. The large diaphragm plants are cost-competitive with new membrane cells because their capital is based on 1970 construction costs. Most of them can operate in the same energy range and they enjoy economies of scale.

They have operations that provide ultrapure salt to feed membrane cells. They also are capable of incrementally and inexpensively increasing caustic soda evaporation capacity to accommodate additional cell liquor from a membrane cell.

All of this, Kienholz says, means that these plants can take advantage of incremental economic situations as they develop, using membrane cells to make incremental expansions that closely match incremental increases in demand. This, he says, is how membrane technology will be used in the U.S.

Not only can companies take advantage of today's membrane technology, they also can be in a position to step into futuristic technology in the late 1980s or early 1990s. This technology includes membrane cells that use oxygen- (or air-) depolarized cathodes to lower power levels to about 1600 kwh per electrochemical unit.

Kienholz believes that, used properly, technology will play a key role in helping U.S. chlor-alkali companies become stronger and better able to serve their customers for the remainder of the 1980s. The hitch is that there will be fewer companies. □

Enzymes Business Attracting New Producers, Technology

Several large chemical firms have entered the merchant market; recent advances in biotechnology promise to improve production methods

Patricia L. Layman, C&EN London

For an industry that goes back even beyond biblical times, the enzymes business is taking on some traits characteristic of the modern chemical industry. It is seeing an increasing emphasis on specialty products. It is seeing an increasing interest among producers in the potential of the latest developments of biotechnology. And more and more it is seeing the entry of large chemical companies willing to bankroll a marketing effort to break the hold of the companies that historically have dominated the business.

Enzymes add up to about $390 million in worldwide sales, up from an estimated $300 million in 1979. It is a highly stratified business. Two suppliers—Novo Industri of Copenhagen, Denmark, and Gist-Brocades, of Delft, the Netherlands—account for about 65% of total worldwide sales, and another seven companies contribute about 17% of total sales.

On the other side, most of the enzymes business is made up of sales of only 16 enzymes, out of the hundreds identified. One class, starch conversion enzymes, constitute about 40% of the total, with three—amylase, glucose isomerase, and amyloglucosidase—the main ones. Detergent proteolytic enzymes account for another 30%, with the remainder of the market split among a dozen other different products.

Hepner: highly stratified business

Those are some of the conclusions one could draw from a recently completed study of the enzymes business, conducted by Leo Hepner and Celia Male of chemical consulting firm L. Hepner & Associates, London.

Fortunately for the industry, however, the two largest categories of products, starch conversion and detergent enzymes, are both relatively fast-growing businesses, according to Hepner and Male. They each will see real-volume growth of about 5% per year over the next five years, the two consultants predict.

Of the two enzyme types, detergent enzymes probably have more potential for continuing good growth. Although the market for enzymes in detergents is fairly well satisfied in Europe, market penetration is still low in most of the rest of the world. For example, in the U.S., enzyme producers still are recovering from the great debacle of more than a decade ago, when worker-safety questions, since resolved, pushed detergent makers into dropping enzymes from formulations. At that time, presoak products were promoted widely, but now manufacturers quietly are adding them to formulations to boost efficacy and performance.

Starch-conversion enzymes, on the other hand, will continue to hold onto the largest portion of the enzymes market and will continue to grow in sales, but the dramatic growth of the past several years will begin to settle down. Growth will continue in the U.S., of course, but the market already is close to being saturated for high-fructose corn syrup, and has slowed temporarily for production of alcohol for gasohol. Other geographical areas are not nearly so promising.

For example, a sizable potential market for starch-conversion enzymes in Brazil never did pan out. Marketers figured they would be selling enzymes to convert cassava-derived starch to sugar for fermentation to alcohol for Brazil's fuel program. But the supplies easily fermented to alcohol without enzymes.

And in the other market whose size is equivalent to the U.S.—Europe—use of starch-conversion enzymes has been blocked artificially by the twists and turns of European Economic Community quotas. The quotas severely limit high-fructose corn syrup production on several points.

Such syrup would be derived from corn, imported from Canada and the U.S., and would compete directly with the sugar beets grown in Europe where, among its other food-surpluses, there is a "sugar mountain." There are several small plants for making high-fructose corn syrup. But output throughout EEC is rationed to a total of just over 200,000 tons per year, Male points out. In the U.S., with a comparable population, output is approaching nearly 4 million tons per year.

Other parts of the world, however, will help contribute to the growth of starch-conversion enzymes. Pfizer, for one, has decided there is promise in South America, and it has made a commitment for making the enzymes there. Japan is increasing its use of starch-based sweeteners, and Thailand is turning its manioc into sweeteners. For better or worse, the developing nations are turning to processed foods and such sweeteners are an integral part of the processed foods industry.

A few enzyme markets are flat or growing too slowly to be of much interest to anyone other than those already in the business—enzymes for textile desizing, for example, or for leather-bating. Other areas are more buoyant, with sales growing for rennet, for instance, used in cheese making, because cheese consumption is rising.

But other areas are somewhat less promising for the near future. Hepner and Male see little future in cellulose enzymes, over the next five years, for breaking down waste cellulose for glucose. Perhaps most important, there would be a stigma against using the resulting product in foods. And other potential uses—for further conversion to industrial alcohol, perhaps—are limited by unfavorable economics owing to relatively high costs of collecting and processing what otherwise would be cheap raw materials.

Similarly, lactase faces a sluggish near term, although sales will "chug along," says Hepner. There is potential for its use to upgrade whey fractions and lactose, hydrolyzing them to glucose and galactose syrup. But at present, neither price nor availability has given manufacturers any incentive to turn from their present course of condensing and drying whey and whey fractions for animal feed.

However, there are enough areas of growth to entice new producers into the business or convince present producers to expand into other markets. Pfizer's decision to enter the starch-conversion enzymes market in Brazil adds to its production in Mexico of detergent enzymes. It has kept up production there, although it ceased production in the U.S.

Enzyme industry shapes up this way for producers . . .

	$ Millions
Novo Industri	$145
Gist-Brocades	106
Seven other firms	70
20 remaining firms	70
TOTAL	$390

. . . and for products

	% of total market
Starch conversion[a]	40%
Detergent enzymes	30
Miscellaneous, about 12	30

[a] Amylase, glucose isomerase, and amyloglucosidase.
Source: L. Hepner & Associates (London)

One of the most recent to enter the merchant market is CPC International. CPC is a major captive user of enzymes, particularly starch conversion enzymes for its corn syrups, and the company often sold excess to the merchant market. But its decision to put up a U.S. plant (location undecided yet) signals a new commitment to the business.

Other captive producers are potential entrants into the business—ADM, for example, or distillers such as Hiram Walker and Seagram, or the French starch converter Roquette. In Finland, captive producer ALKO and Finnish Sugar Co., the state's alcohol producer, both are building small enzymes plants for the merchant market.

Coming in by another line of attack, Corning Glass and Genentech early in 1982 established the joint venture Genencor for marketing immobilized enzymes. The venture seeks to exploit Corning's technology for immobilizing the materials, while Genentech provides its recombinant DNA techniques for producing enzymes. The unit bought a small enzyme plant from Rohm & Haas to start up with.

How well the venture does remains to be seen. The major market that immobilized enzymes have found has been in production of high-fructose corn syrup. Immobilized glucose isomerase just fit the bill, and, indeed, probably made such production economically feasible. Beyond that, however, there are reservations held by at least some industry observers. "Biotechnology has been the buzzword in enzymes," says Hepner. "But while it may or may not affect the market eventually, it is not commercial now."

Genentech officials naturally are enthusiastic about the potential of using recombinant DNA to produce enzymes. The San Francisco-based Cindany already has taken aim at the market for rennet, a key enzyme in cheese making, now made by microbial fermentation or derived from calf stomachs.

"Rennet is getting in short supply," says a Genentech official. "There eventually will be a problem unless something else is done, especially as cheese consumption goes up." And other food processing and fine chemical enzymes may be approaching a similar supply situation, explaining rennet's marketing emphasis.

Genencor, the official says, will be able to use its technology "to look at novel enzymes," and to replace energy-intensive methods with its own, to produce "high-quality, low-cost ingredients." The device, the official adds, to find a more efficient way to produce very large quantities of enzymes is the major push for the enzymes business today.

Thus, how well biotechnology fits in remains unanswered. Although even traditional producers are hedging their bets—Chr. Hansen, based in Copenhagen, which probably has nearly 50% of the world market for rennet, has set up a marketing agreement with Genencor, for example—new manufacturers face a conservative and stable market that can be difficult to crack.

Rennet, for example, is a well-established market. And although cheese consumption is rising as people increasingly turn to cheese for a replacement for meat protein, more rennet per unit of cheese is not demanded. Growth is linked solely to growth of cheese.

"If a product made by recombinant DNA techniques is really identical to calf rennet, and much cheaper, cheese makers would change," says consultant Male. "But if it is the same price, they probably wouldn't bother."

Instead, the consultant predicts, established companies will try to keep ahead of the marketplace by developing specially tailored enzymes able to justify higher prices. Hepner cites, for example, Novo's recent introduction of a high-temperature amylase and a low-temperature rennet. The high-temperature amylase, which is patented, can be used under high processing temperatures for starch conversion.

Manufacturers therefore can devise continuous steam- or pressure-cooking conversion processes. Similarly, much of the rennet sold, derived from microbial fermentation, is not deactivated by pasteurization, so it can keep acting beyond the desired level during cheese making. Calf rennet is deactivated. Novo's new rennet, though microbially produced, also is deactivated by heat—it is thermally labile—so it won't continue activity longer than desired and degrade the cheese.

The key point for a manufacturer is "to look at the weaknesses of what is on the market now, and devise ways to improve upon them for customers," says Male—typical specialties marketing strategy. "The same product can be a specialty or a commodity depending on who makes it," adds Hepner. "You couldn't just come in with a me-too product, unless it was considerably cheaper. Then you are in the price-cutting business, and you are back to commodities again."

Manufacturers also must keep an eye out for new markets for unexploited enzymes. A case in point is pullulanase, for the brewing industry, which has become of interest because of the "light" beer phenomenon. If the excess carbohydrates left after regular brewing are removed or fermented to alcohol, fewer calories are in the beer, is the marketing claim that brewers such as Miller and Budweiser have used with good effect in the U.S., according to Hepner and Male. Pullulanase is "the ultimate method," when coupled with β-amylase. The two enzymes break down the branched-chain carbohydrates still left in the brew, which then can ferment into alcohol—and provide the brew that sets sports pitchmen into action, promoting the products. □

U.S. chemical trade surplus will continue

Washington, D.C.

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

Through the first half of the year, chemical exports were running about 6% behind their pace in 1982, but chemical imports were 14% higher than they were last year.

At these rates, the U.S. chemical industry could end up the year with a trade surplus of only $8.9 billion. In 1982 that surplus was $10.4 billion, and only three years ago it stood at a record $12.1 billion.

Because of developments such as these, chemical trade has taken a beating in the press as well as in the marketplace, says Karl D. Loos, a senior staff member in the chemical industry section at consultant firm Arthur D. Little Inc., Cambridge, Mass. Suggestions that the U.S. will become a net chemical importer by 1990 are not uncommon, he says.

However, Loos disputes these doom-and-gloom reports. "The U.S. positive balance of trade in chemicals is not in jeopardy," he told a meeting of the Chemical Marketing & Economics Division.

He points out that chemical trade has shown remarkable stability and resilience over the years. He believes that most foreign trade is based on sound, long-term business needs. And, although U.S. exports of some commodity chemicals certainly will shrink as new producers enter international markets, Loos expects this loss to be more than offset by increasing U.S. exports of more technically advanced, higher value-added chemical products.

According to Loos, pessimistic attitudes about the future of U.S. chemical trade are based on several well-publicized factors:

- The shrinking U.S. energy and feedstock cost advantage.
- Increased competition from energy-rich nations, in which governments do not always respond to the profit motive.
- Chronic, worldwide overcapacity in many chemicals, particularly in basic petrochemicals.
- Stagnant industrial and economic growth.
- The strength of the U.S. dollar.

Each of these arguments is reasonable, says Loos. However, they lose force when viewed in the broader context of a global industry. For instance, Western Europe had a significantly worse feedstock position than the U.S. between 1973 and 1980, yet its chemical exports grew faster than those from the U.S. Countering other arguments, Loos says that the emerging competition from energy-rich nations will come from a very narrow product spectrum that includes mostly C_1 and C_2 commodity chemicals.

Leading U.S. exported chemicals remain fairly constant

	1982		1980	
	Rank	Value ($ millions)	Rank	Value ($ millions)
Diammonium phosphate	1	$ 679	1	$1096
Low-density polyethylene	2	417	2	505
Phosphoric acid	3	407	9	281
High-density polyethylene	4	323	5	297
Polypropylene	5	286	6	287
Styrene	6	276	3	389
Acrylonitrile	7	248	—	120
Catalysts	8	236	10	239
p-Xylene	9	228	11	221
Polyester fiber	10	226	7	142
Urea	11	227	4	312
Polyvinyl chloride	12	171	12	182
TOTAL		$3726		$4081

Source: A. D. Little Inc.

He believes that meanwhile chronic worldwide overcapacity could turn into chronic shortages in a period of economic recovery. This is particularly true because of the large amount of basic petrochemical capacity already shut down or scheduled to be shut down and the cancellation of several large international petrochemical projects.

Nor is the dollar's strength a new problem for U.S. exporters. The hangup is that, after the spectacular rise in U.S. chemical exports between 1976 and 1980, many trade analysts find it hard to accept old, established trade relationships.

Loos says that, contrary to what many think, chemical foreign trade is not a "single entity." Instead, it involves several distinct types of trade. One of these is technological trade, the most logical of all trade. One country exports a single chemical that is not produced in the importing country, often because of a technological advantage.

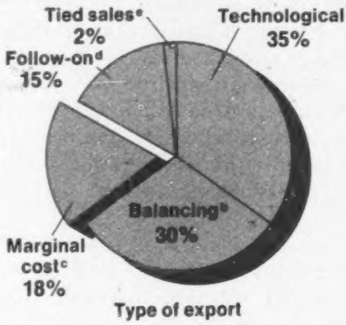
Balancing trade refers to supply-demand imbalances between countries or a company's international production system. This type of trade often occurs because of the large scale of new chemical plants compared to market growth and often involves fast-growing chemical commodities.

Follow-on trade occurs as companies expand their international operations, marketing their entire product line in a foreign country through exports even though only a few of their products are produced there.

Another type of trade is marginal cost trade. This is the most disruptive type of trade to market conditions in importing countries. When operating rates are low, companies seek export markets at less than full market price. This trade often leads to worldwide price cutting, unprofitability, and dumping.

In addition to these types of trade, tied sales can involve long-term barter agreements or compensation deals.

Marginal cost exports are small share of total exports



[a] Depends on specialized proprietary technology. [b] Corrects imbalances between supply and demand. [c] Exports at less than full market price. [d] Occurs as companies expand their international operations. [e] Related to long-term barter agreements on compensation contracts.
Source: A. D. Little Inc.

Unfortunately, says Loos, marginal cost trade gets most of the publicity. And it is this trade that forms the basis for many pessimistic forecasts about the U.S. chemical trade future.

However, marginal cost trade accounts for only 18% of U.S. chemical export volume, technological trade commands 35% of exports, and balancing trade chips in with another 30%.

Even in marginal cost trade, there is more than meets the eye, says Loos. For instance, synthetic resins are a large export item that trade pessimists cite as a sure loser to new international competition. But Loos points out that, although the low-value, major thermoplastics accounted for 60% of resin export volume last year, much higher-value specialty resins accounted for 65% of the value.

Forecasting the future of U.S. chemical exports is not easy. Each type of foreign trade responds differently to changes in the economic cycle. Individual chemical exports may fit into more than one type of trade category. Fluctuations in currency values do have to be pumped into the equation.

In addition, chemical export growth is far from uniform. Between 1980 and 1982, the value of fertilizer exports dropped 39%, while that of medicinals and pharmaceuticals rose 18%.

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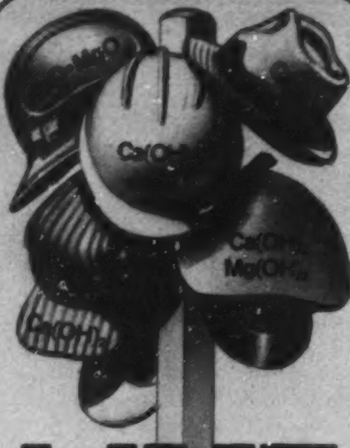
Loos says that a correlation exists between value-added and export performance. Products with high value-added indexes met or exceeded the industry's average export performance. Those with a low value-added index saw their exports decline significantly faster than the industry as a whole.

Even during the worldwide recession, Loos says, there were some bright spots in the U.S. chemical export portfolio. These bright spots, he adds, reflect the security of export markets that fit into the technological or follow-on trade categories.

To forecast future chemical trade trends, it helps to know which of today's leading chemical exports will be future winners and which will be losers. Arthur D. Little tries to determine its winners and losers with a chemical trade risk analysis matrix that it developed. The matrix uses two conventional components of risk analysis. One is exposure, or the amount of revenue at risk. The other is uncertainty, which Loos defines as the probability of a chemical losing export share to production outside the country.

Where a product is spotted on the matrix pretty much determines its future export potential, or lack of it. For instance, the C_1 and C_2 chemicals have high uncertainty and are likely to lose export share. C_3 chemicals, aromatics, phosphate fertilizers, and ethylene dichloride are among the products with a moderate degree of uncertainty. They probably will maintain their export strength, Loos says, although their major export markets may change. The more technologically advanced and complex chemicals, he says, have a secure position in the export market and are likely to grow. Catalysts are an outstanding example.

Based on this same matrix and 1982 chemical exports of $19.9 billion, Loos says that chemical exports representing 22% of that value probably will decline in the future. On the other hand, products amounting to 36% of that value look like winners with a good chance of export growth. That is why he doesn't consider the U.S. chemical trade balance to be in jeopardy, even though trade patterns of the past may give way to new patterns. □



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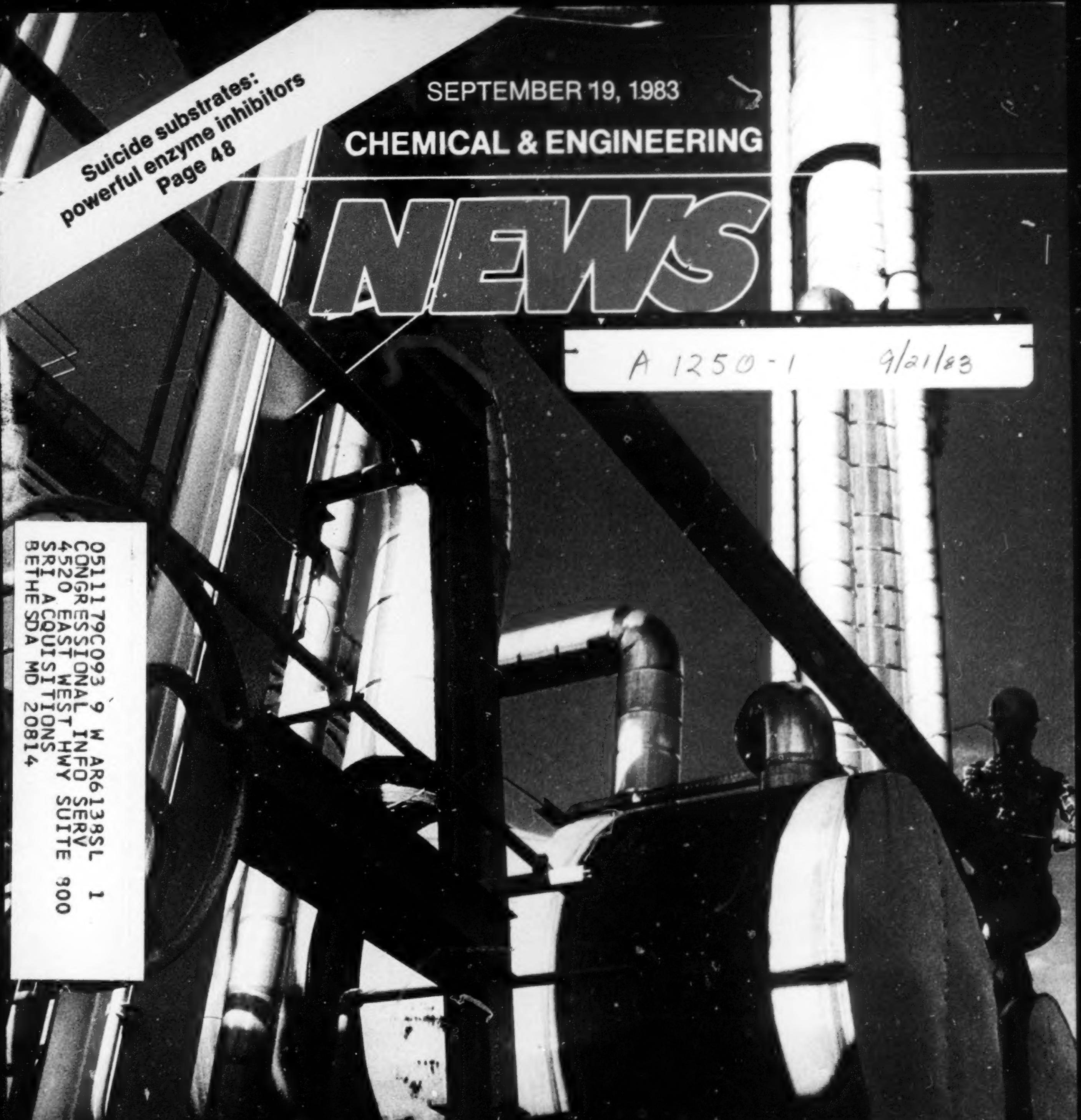

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Industrial Gases

Recovery brings new reality

A Key Chemicals Review Page 9

Cover: Airco's carbon dioxide plant at Augusta, Ga.

CHEMICAL & ENGINEERING
NEWS

Volume 61, Number 38
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SEPTEMBER 19, 1983

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- **NSB commission recommends plan to improve education in math and science.** **Page 7**
- **President's proposed bill allows joint R&D ventures without fear of antitrust suits, protects patent holders.** **Page 7**

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International

IUPAC to allow individual chemists to become members, under its Affiliate Membership Program, through their societies. **Page 14**

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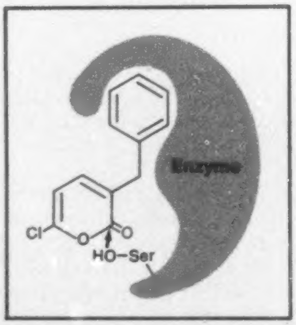

Special Report

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Industrial Gases Recovery from Recession Is Mixed

Nitrogen demand is up again, but oxygen use continues to lag and carbon dioxide is mired in supply problems; long-term growth has slowed

Bruce F. Greek, C&EN Houston

After a very long period as one of the U.S. chemical industry's best growth areas, industrial gases producers are finding that even they aren't immune to recessions or reduced long-term growth. The latest recession significantly slowed production and chopped forecasts for future growth by half or more.

Throughout the 1970s, industrial gases output grew at 10% or more annually. Plant expansions came at a torrid clip, unfortunately more than production growth. Enter the 1980s; production suddenly changed, but plant construction didn't. The classic result is that combined production of oxygen, nitrogen, and carbon dioxide—the major gases whose immediate market outlooks appear on the following pages—is heading into about 5% annual growth through most of the 1980s, and overcapacity has found a new home.

Plant expansions are continuing, although at not nearly the rate of two years ago. Net capacity additions could be well down as producers close old plants where demand is off and electric power costs are up. In general, newer plants are much more efficient than plants built even five years ago, industry analysts say. The new plants are fully computerized to reduce power consumption and other costs, such as labor. Distribution methods for the truck-based merchant part of the industrial gases market also have been computerized as much as possible to reduce their rapidly increasing costs.

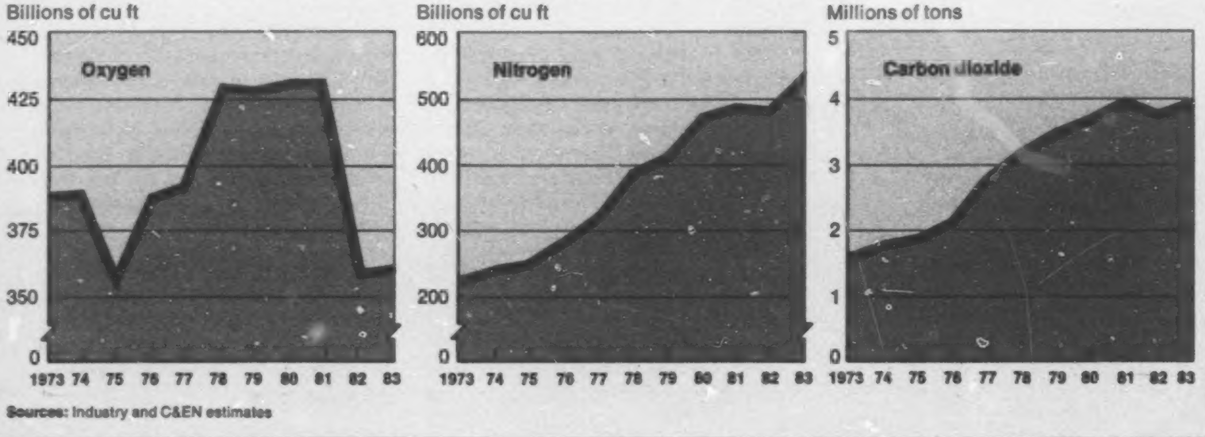
Key Chemicals

Overall nitrogen and carbon dioxide demand will continue to grow more rapidly than will demand for oxygen, which is becoming the industry's poor cousin.

Nitrogen has an advantage in that many diverse uses developed for it over the past 20 years, buffering it from general economic downturns. New developments still are coming, for example use in the steel industry to shroud processes.

Nitrogen's coproduct, oxygen, in contrast has one major use in metals which takes nearly two thirds of production. Metals' dominance will ease only a little over the next five years. Efforts to find new uses, mainly in the area of atmosphere enrichment, will help somewhat but probably will not overcome the decline in use in basic oxygen furnaces making steel.

Like both oxygen and nitrogen, carbon dioxide is a coproduct, but in an entirely different way. It is tied heavily to ammonia production, the source of 60% of it. Another 30% or so comes from oil refineries. Carbon dioxide production currently is held down by poor demand in its coproducts' other markets.


Carbon dioxide and nitrogen regain growth track, but oxygen lags

Sources: Industry and C&EN estimates

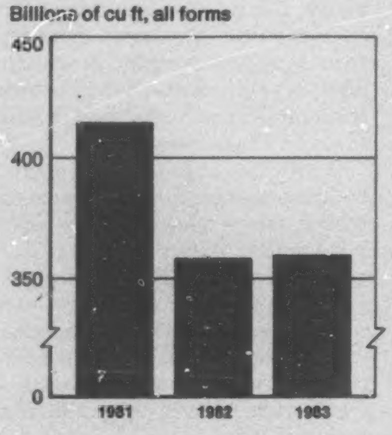
Key Chemicals

O_2

Oxygen

- ***Demand still low***
- ***Capacity increasing***
- ***Prices discounted***

PRODUCTION



HOW MADE

Separated from air at low temperatures

MAJOR END USES

Primary metals manufacturing 30%, metals fabricating 35%, health services 15%

FOREIGN TRADE

Negligible

PRICES

49 cents per 100 cu ft plus shipping and equipment charges (merchant)

COMMERCIAL VALUE

$425 million for production, 1983

Oxygen differs from the other big-volume industrial gases, nitrogen and carbon dioxide, in that one major industry dominates demand—metal making and fabricating. And alas, a big part of metal demand is in the woebegone steel business. So it is oxygen's fate that steel's problems have brought its former robust growth to a halt.

Since steel now is in partial recovery from its deep slump from the second half of 1982, oxygen also has begun to recover. Oxygen demand is expected to move up enough from its depths of last winter to about match 1982 demand of 358 billion cu ft. Most industry sources call the 1983 total within a few billion cubic feet of the 1982 figure, although one optimist predicts an increase of 3% to 370 billion cu ft.

Even a 3% upturn isn't much comfort for producers who absorbed a 17% production drop last year from 431 billion cu ft in 1981. The 1983 upturn then isn't doing much to improve plant use rates or pick up coverage of overhead and capital costs. It will be quite some time before the 1981 oxygen production level is regained unless steel goes into a much stronger than expected recovery.

Estimates of current average operating levels of air separation plants range between 60 and 65% of the nameplate capacity, or 70 to 77% of effective capacity. The usual operating procedure for plants with demand for product well under effective capacity is to fill the plant storage tanks and then shut down until more product is needed. Such a scheme cuts overall energy costs compared to continuous operation of the plant at lower fractions of capacity.

So estimates of operating rates include these oxygen plants currently shut down. This is the case, for example, at steel complexes whose basic oxygen furnaces also are down. In other cases, a new, more efficient air separation plant may be close enough to the user that shipping costs are still worth it compared to costs of an old onsite plant. As a result, the old plant is put on standby until demand rises enough to justify restarting it.

These "tonnage" oxygen plants, usually located close to customers with a pipeline connection, fill about 80% of oxygen demand. The remainder generally is served by "merchant" oxygen plants, with product delivered in liquid form by truck to a variety of smaller users.

The distinction between "tonnage" and "merchant" is a bit blurred: Some merchant oxygen users actually have pipeline connections and some small users have mini onsite air separation plants.

Current overcapacity in oxygen keeps downward pressure on prices even though plants' energy costs continue to rise. List prices have stayed flat, although some of the widespread discounting is being reduced.

Tonnage oxygen plants tied to a single, large-volume user have take-or-pay contracts, some of which are old and don't return enough to justify the investment. Contract renewals on these plants are proving difficult to negotiate in view of uncertainties in the steel industry and growing competition among oxygen producers.

Nonmetal outlets for oxygen are many and varied, with health services, chemical manufacturing (ethylene oxide, for example), and enrichment of high-temperature atmospheres being the largest. Growth in demand in these and other uses is not expected to be high this year, partly because of customers' efforts to reduce costs and partly from the lingering effects of the 1982 recession. Because of their relatively small size, none of the nonmetal uses will have much effect on overall oxygen demand in the next few years. However, their share of total oxygen consumption could increase if demand for oxygen in steel stays low.

These other uses of oxygen are almost entirely merchant sales of the gas, generally small in volume and variable in demand. As a result, estimates of the quantities going into these applications are rough at best. Health services probably accounts for a bit less than 15% of merchant oxygen consumption, perhaps 10 billion cu ft per year, according to industry sources.

Saddled with such conditions of limited growth, overcapacity, and low profitability, oxygen is not the hot product it used to be. It clearly is no longer the main reason for building most air separation plants.

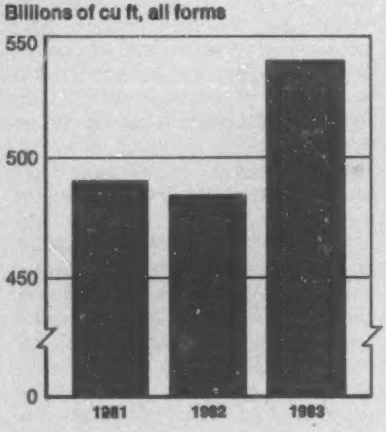
Key Chemicals

Nitrogen

N_2

- ***Demand rebounding***
- ***Capacity to grow***
- ***Prices up a bit***

PRODUCTION



HOW MADE

Separated from air at low temperatures

MAJOR END USES

Blanketing atmospheres for chemical processing 25%, electronics manufacturing 15%, enhanced oil recovery 15%, metals treating and processing 15%, aerospace 5%, meat and poultry freezing 5%

FOREIGN TRADE

Negligible

PRICES

Merchant sales 44 cents per 100 cu ft plus shipping and equipment charges

COMMERCIAL VALUE

$500 million for production, 1983

Nitrogen experienced a slight break in its long-term high growth in 1982, but it should easily get back on track in 1983. This rebound will keep nitrogen volume well ahead of oxygen from now on, unless by some remote chance a big new use for oxygen should develop.

Nitrogen appears to have developed its own big new use over the past few years—enhanced oil recovery (EOR) to boost output from old oilfields. This use now will take 15% of all nitrogen consumed in the U.S. this year, up from next to nothing only five years ago.

EOR accounts for a lot of nitrogen's forecast production gain for 1983—as much as 12% over 1982 to reach a total of 540 billion cubic feet and possibly more. Production in 1982 of 484 billion cu ft was off 1% from 1981 as user industries staggered under the recession.

Plant capacity for nitrogen is an elusive figure because demand varies greatly with location. In some cases little, if any, nitrogen is sold from an air separation plant because the plant's primary purpose is to produce coproduct oxygen. At other locations—for example, in an oilfield for EOR—oxygen actually is discarded because the plant is too far from oxygen markets. Hence, in most air separation plants, operation is adjusted over a wide range to produce the two gases in relation to the nearby demand. The gas in lesser demand, more often nitrogen, also is used partly as purge gas to remove unwanted impurities, further complicating capacity estimates.

The merchant market for nitrogen is larger than that for oxygen, accounting for more than 25% of production. This market share varies from year to year as customers shift from buying nitrogen on the outside to either making their own in small air separation plants or connecting to a pipeline.

The diversity of nitrogen markets resulted from producers' efforts over many years to find some way to sell this formerly discarded coproduct of many air separation plants. Oddly, producers succeeded so well that they now have the reverse problem at many plants—looking for new oxygen uses to balance demand for nitrogen.

Blanketing atmospheres in various industrial processes—used to ensure product quality and plant safety—are the largest use of nitrogen, perhaps 25% of the total. This use declined somewhat in last year's recession, but recovery is well under way. However, blanketing is no longer a fast-growing use as it was during the boom in previous decades in chemical and oil refining capacity. Longer-term growth forecasts are now much below the former 7 to 10% annual rates.

EOR is now the fastest growing use of nitrogen but from a small base. EOR nitrogen plants usually are single-use units in oilfields, often far from any industrial area. Their former red-hot growth is settling down now under the dampening influence of the world oversupply of oil, lower oil prices, and lower oil demand. Longer-term, availability of suitable oil-containing formations could become the most important question on EOR use of nitrogen.

The electronic use of nitrogen also seems to be in a slower growth stage. Quality requirements here continue to rise in line with quality requirements for the chips used in circuits. The ultra-high-purity end of this market, though small in volume, commands a steep price. Growth in this area has throttled down to 10 to 20% annually from the former sizzling 30 to 40% rates.

The metals treating and processing use of nitrogen is really another blanketing application. Nitrogen is used in process atmospheres in galvanizing, heat treating, metal drawing, and the like. Quality demands for the finished product are keeping this growth at 7 to 10% a year.

The many other uses of nitrogen also show some high growth rates, although some are well beyond their peak growth years. For example, nitrogen use in quick freezing of red meat, poultry, and specialty food products has slowed way down as a result of the recession and changes in eating habits. None of the small uses of nitrogen are expected to add much more than 1 billion to 2 billion cu ft to total demand in 1983.

Even so, the combination of gains in some small uses and major gains in large uses has pulled nitrogen demand back to a decent overall growth rate. Prospects indicate a continuation, hampered a bit by the need to find some way to revive coproduct oxygen.

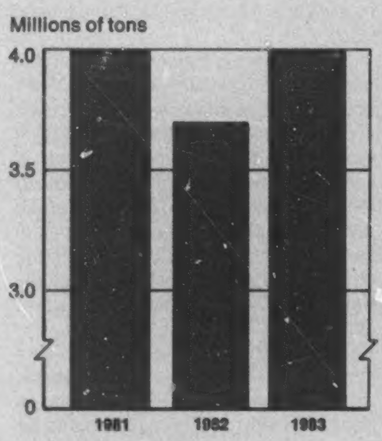
Key Chemicals

CO_2

Carbon Dioxide

- ***Supply limited***
- ***Some capacity shut***
- ***Prices firmer***

PRODUCTION (nonoilfield)



HOW MADE

Recovered from synthesis gas in ammonia production, from refinery production of hydrogen, from fermentation processes, and from natural wells

MAJOR USES (nonoilfield)

Refrigeration 30%, beverage carbonation 25%, urea manufacture 15%

FOREIGN TRADE

Negligible

PRICES

About $77 per ton for large uses; prices vary by region

COMMERCIAL VALUE (nonoilfield)

$150 million for production, 1983

Carbon dioxide has become an industrial gas with two lives—one in the oilfield and the other everywhere else. Oilfield use, mainly in enhanced oil recovery (EOR), is the larger but isn't reported to the Bureau of the Census. So production data are mainly industry analysts' guesses.

To make the data situation worse, the all-other category for carbon dioxide may well include small amounts used in EOR. Most nonoilfield carbon dioxide is a coproduct with ammonia or refinery hydrogen. Smaller quantities are recovered from fermentation-ethanol processes.

The oilfield side of carbon dioxide is quite different from the gas's traditional merchant and captive markets. Industry analysts estimate that EOR carbon dioxide is now much greater in volume. This carbon dioxide comes almost entirely from natural wells, which contain gas with carbon dioxide content ranging from as little as 10% up to nearly 100%. This carbon dioxide is produced, separated from the other gases, and pipelined to injection wells, where it is put into suitable geologic formations to boost oil output. It in effect acts as a solvent for some of the underground hydrocarbons, causing them to be displaced from the formation structure and flow toward producing wells. Many techniques, using carbon dioxide alone and with other materials, are being either used or investigated in EOR.

Additional smaller quantities of carbon dioxide are used in the oilfield to maintain pressure and to carry other substances whose job it is to keep pores open in the structure to allow the oil and gas to move to a well bore. Often, this carbon dioxide is supplied by merchant producers.

Outside the oilfield, carbon dioxide has a supply problem owing to its major sources in ammonia production and refineries. Both sources have been reeling from the aftereffects of the recession in fuels and the continuing recession in fertilizers. The result is that carbon dioxide production is controlled now by noncarbon dioxide markets. Some plants are shut down; others are running full tilt.

With an eye toward such supply limitations, industry sources expect that 1983 nonoilfield carbon dioxide production will be about 4 million tons, up 8% from 1982's 3.7 million tons. At least, this gain represents full recovery from the 1982 recession. About 60% of this carbon dioxide will come as a coproduct of ammonia production, with nearly another third from refineries.

Estimates of carbon dioxide capacity are completely up in the air, analysts say, because of questions about operability of some plants. If the severe drought and the government's payment-in-kind programs this year cause downstream fertilizer demand to jump in 1984 for increased plantings, then some marginal plants supplying carbon dioxide might be restarted. However, some EOR-carbon dioxide plants might be shut down or moved without general knowledge.

The use pattern in nonoilfield carbon dioxide isn't changing much. However, analysts say, if supply continues limited, causing prices to rise, some refrigeration uses could be taken over by competing nitrogen or even mechanical refrigeration. Higher-priced carbon dioxide might even suffer in use in high-value foods such as red meat, which are quick-frozen with carbon dioxide to preserve quality. There may be a limit here in food processors' willingness to buy aesthetics. Overall, food refrigeration continues to be a good growth area for merchant sales of carbon dioxide.

The second largest merchant use of carbon dioxide is beverage carbonation. The soft drink business is growing not much faster than constant-dollar gross national product. The advent of light beers is beginning to help this use, but the base is still small.

Carbon dioxide's major industrial use, most of it captive, is in making urea. Urea production has benefited over the years from farmers' greater use of solution-type fertilizers, but this year the farm business is so bad urea has suffered too. Urea may recover next year if farm commodity supply tightens and prices rise.

No other uses of carbon dioxide will have much effect on total nonoilfield production. For both merchant and captive producers, the key to output volume and profitability this year is somewhat out of their hands, resting with ammonia plants and oil refineries.

Dow's Oreffice looks ahead to 1984
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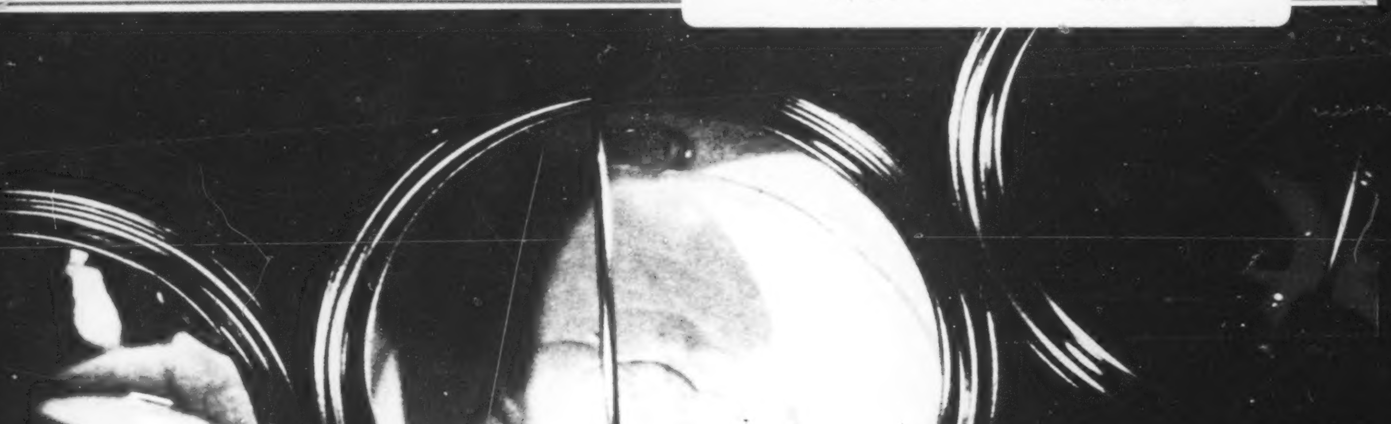

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Paint industry recovers recession's losses
Page 25

Cover: Photo courtesy of Glidden Coatings &
Resins division of SCM

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OCTOBER 3, 1983

News of the Week

- **Evidence of new contamination at Love Canal site forces EPA to revise cleanup plan. Page 4**
- **EPA's plan to control acid rain doesn't sit well with other federal agencies. Page 5**
- **University of Nebraska chemistry professor discovers method to make hydrazine directly from gaseous nitrogen. Page 5**
- **Five employees of Seveso, Italy, trichlorophenol plant found guilty of negligence in dioxin contamination disaster. Page 5**

Business

Paul F. Oreffice, chief executive officer of Dow Chemical and SCI Medalist, discusses company's recent problems. **Page 7**

Government

Science advisory boards of the Defense Department, criticized in reports, examined at House subcommittee hearings. **Page 11**

GAO review of the Environmental Protection Agency's attempts to regulate air pollutants uncovers labyrinthine process. **Page 12**

Science Policy

NAS's Committee on Science, Engineering & Public Policy hopes to revive academy role in national science policy debates. **Page 15**

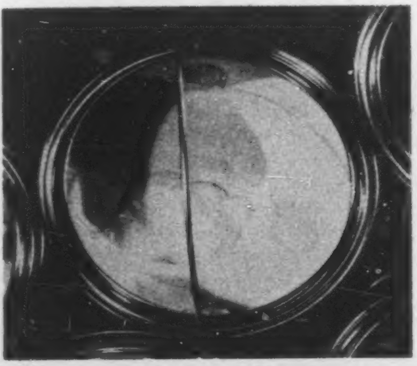
Science

Surface-enhanced Raman scattering is not yet fully understood but researchers believe it has tremendous potential. **Page 22**

ACS News

Nominations are requested for ACS awards to be given in 1985; two new awards have been added to the list. **Page 45**

Society's Younger Chemists Committee presents regional chemical career counseling conferences on college campuses. **Page 47**



Paint Report

Rise in production of paints, coatings is due to increased housing starts, auto output, and consumer use. Page 25

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Operation of Defense's Science Advisory Boards Aired in Hearings

House panel discusses two reports questioning boards' compliance with governing policies, operating procedures, and legal requirements

The House Government Operations Subcommittee on Legislation & National Security held hearings late last month on what chairman Jack Brooks (D.-Tex.) called the "very serious and disturbing findings" of two reports on the operations of science advisory boards of the Department of Defense.

The first report, which was issued in July by DOD Inspector General Joseph H. Sherick, concluded that the Defense Science Board's compliance with governing policies, operating procedures, and legal requirements was clearly inadequate and that lack of documentation concerning DSB task force meetings left the objectivity of its recommendations open to question (C&EN, Aug. 22, page 15).

The second report, released at the hearings, was prepared by the General Accounting Office and concerned the operations of the Army Science Board, the Air Force Scientific Advisory Board, and the Naval Research Advisory Board. GAO found that "the services do not always follow appropriate procedures in the operations of the scientific advisory committees."

The three committees conduct their work primarily through panels—usually created for one year or less. Each panel performs a specific task or undertakes a specific study. In reviewing the financial disclosure statements of 117 panel members, GAO found that 32, or about 27%, were employed by or had financial interests in organizations with contracts in areas that could be affected by panel recommendations, GAO head Charles A. Bowsher told the subcommittee.

Further, Bowsher said that whereas the Federal Advisory Committee Act requires that panel membership be fairly balanced in terms of representative points of view, the DOD directive which implements the act does not address the issue of balance at all. The lack of documentation of the steps taken by the Army and the Air Force in the selection of panel members, the direct involvement of DOD personnel in panel decision making, and noncompliance with procedures for meeting announcements and minutes could lead to questions about the objectivity of the Army and Air Force panels, GAO charges.

The operating procedures of the Naval Research Advisory Committee also could lead to questions concerning the objectivity of its panels, GAO says. However, its panel members do not have to file financial disclosure statements because the Navy considers them to be employees of Catholic University, Washington, D.C., which is under contract to provide support for the research advisory committee's studies. That also means that notices of panel meetings do not have to be published in the *Federal Register* and minutes of the meetings do not have to be taken.

Asked to investigate charges that the science panels were essentially an "old boy network," GAO analyzed the panel's five-year membership to determine if the same organizations continually provide individuals to serve on panels. During that period a total of 1223 assignments were filled by 1049 individuals—representing 209 employers. The two largest categories of panel members were either self-employed consultants (140) or DOD employees (115). Twenty-six employers provided individuals to fill five or more positions in at least one of the five years. Twelve of the employers pro-

Top 12 contributors to DOD science panels

Panel members	1982	1981	1980	1979	1978	TOTAL
Aerospace Corp.	2	10	6	6	3	27
Boeing	6	2	6	4	5	23
Honeywell	5	5	6	2	2	20
Hughes Aircraft	8	8	4	3	2	25
Lawrence Livermore National Laboratory (U of California)	1	7	10	5	3	26
Lincoln Laboratories (MIT)	3	8	10	4	2	27
Massachusetts Institute of Technology	5	8	4	12	5	34
Mitre Corp.	6	3	3	5	3	20
National Aeronautics & Space Administration	7	5	6	9	4	31
R&D Associates	8	12	6	8	11	45
University of California	5	7	4	7	4	27
Department of Defense	32	16	32	26	9	115

Source: General Accounting Office

vided individuals to fill 20 or more positions over the five-year period.

Bowsher was most concerned about the participation of military personnel in committee activities. He pointed out that "since panels are established to provide independent advice, the use of military personnel in panel decision-making could lead to questions about how independent such advice is." He suggested that military personnel serve only as advisers or briefers instead of being participants in panel decisions.

Although the GAO report on the three service committees has just come out, DOD has had time to make "substantial improvements" in the operations of the Defense Science Board, according to DOD Inspector General Sherick. He told the subcommittee that financial disclosure statements are being processed, in most cases, in advance of panel members' attending their first meetings. An "ethics counselor" has been appointed to work closely with DSB to ensure that financial interest reviews are complete. Advance notices of all meetings are now being published in the *Federal Register*. Minutes are being taken at each meeting.

The most important outcome of the report, Sherick says, is that a master list of potential task force members is being drawn up. "The concept of such a list is a major improvement over past practices and complies with our recommendations to broaden the universe from which task force members are selected. This is a good start," he told the subcommittee. But he expressed concern over a recent followup review of DSB practices that showed that of 26 consultants on three task forces, only six individuals had not participated on a task force included in the first review and only four were selected from the master list. "I envision a list of at least 1000 names selected from, and recommended by, many diverse disciplines and organizations. I also believe that a continuing effort will be needed throughout the life of the board to ensure that the broadest range of expertise is always available and the list is current. More important, the list must be used as the primary source of task force members," he said.

Janice Long, Washington

GAO exposes maze of air hazard regulations

It is no secret that the Environmental Protection Agency takes a long time to decide on new regulations and that it often has failed to meet the deadlines set by Congress in the various environmental laws. Now, in one of the longest documentations ever of this problem, the General Accounting Office has released a report on the tortuous path the agency follows in regulating hazardous air pollutants.

The GAO review was requested by Rep. John D. Dingell (D.-Mich.), chairman of the Energy & Commerce Subcommittee on Oversight & Investigations. GAO was to find out why it is taking EPA so long to promulgate any rules on new air hazards. It found a maze of review committees, subcommittee panels, and EPA offices all partly responsible for getting out the regulations.

Basically, under the Clean Air Act, section 112, EPA is required to develop standards on any hazardous air pollutants that are not covered by other parts of the law. When a substance is suspected of being a health hazard, EPA prepares a health assessment document that is, by agency policy, approved by the agency's scientific advisory board. When a hazard has been identified, the substance is "listed" as such by EPA. The agency then has 180 days to propose an emissions standard for that substance and must publish a final standard 180 days after the proposed standard. EPA has generally failed to do all of these things.

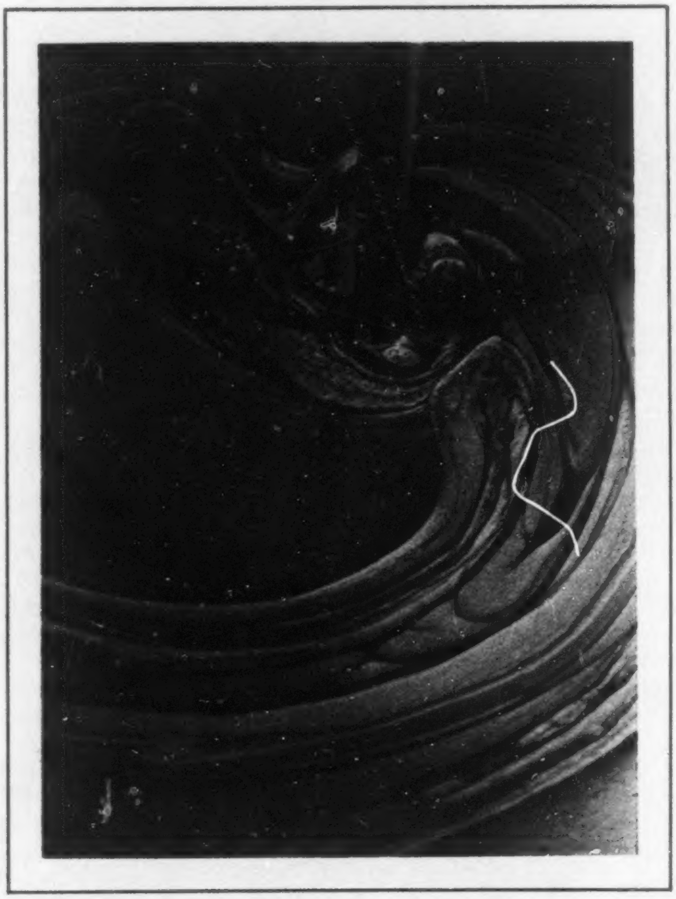
A brief study conducted in 1976 by a contractor listed 632 chemicals that might be possible hazardous air pollutants. By 1977, EPA had cut that list to 43 and eventually ended up with a priority list of 37 potentially hazardous air pollutants. This list has been updated, revised, massaged, cleaned up, and corrected several times since it first appeared, but action on the substances has not come smoothly. EPA has listed only seven compounds as hazardous and promulgated regulations on just four of those. The agency is developing health assessment and standards for another 37 compounds. GAO finds a number of reasons for this sad state of affairs.

Constant policy shifts by various EPA administrators on just what kind of data and peer review are needed for the health assessment documents are the major problem. Work done by the two main offices at the agency, the Office of Air Quality Planning & Standards and the Office of Health & Environmental Assessment, has been jerked around at different times by the addition of new layers of review or by having new deadlines forced on them by lawsuits. The science advisory board is also blamed for some of the delay. It has criticized EPA's methods of assessing hazards and the agency has been slow in making the recommended changes.

GAO claims it is the health assessment document that is the critical problem. The report says that assessments on 19 of the 37 chemicals have been started, but the advisory board has approved only two. EPA claims it takes up to 30 months to get an assessment completed, making a joke of the 180-day deadlines for proposed rules set in the law. Also, delays in getting the assessment documents finished because of lengthy internal reviews have meant that reports containing outdated information have gone to the science board for approval, causing EPA to spend more time and money updating the documents when they weren't approved.

But even when the science board has approved an assessment, EPA hasn't moved. For instance, an assessment of cadmium was approved in 1978, but EPA has yet to propose an emission standard. Toluene's assessment was approved by the board in May 1983, yet EPA has held up action on a standard.

GAO acknowledges that EPA is making an attempt to straighten out the tangled system now in place for evaluating and regulating hazardous air pollutants, but makes no prediction on whether that effort will be successful. Without more resources and relief from the constant barrage of lawsuits that force personnel to leave ongoing projects in order to meet court-ordered deadlines, it seems unlikely the process can ever be significantly faster. ☐



Paint Industry Recovers from Recession's Losses

William J. Storck
C&EN New York

Paint and coatings manufacturers are having it their own way this summer.

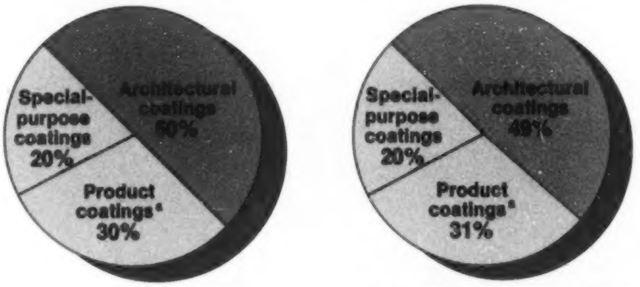
A combination of increased housing starts, rising automobile output, and expanding use by consumers to repaint both the exteriors and interiors of existing houses has served to increase production of paints and coatings dramatically.

According to seasonally adjusted figures from the Commerce Department, production of paints and coatings increased more than 68% between January and June this year, when output reached 97.4 million gal. (Baseline data from the Commerce Department were revamped in January so that comparison with earlier years is not possible.)

The value of manufacturers' shipments didn't quite keep up with production, but it also rose healthily through the first six months of 1983. According to the Commerce Department, this value increased almost 65% between January and June to a seasonally adjusted $854 million.

However, business for paint makers is not always this good. The paint industry is a mature and cyclical business made up of an estimated 1000 manufacturers. Thus, in good times output grows slowly, but in bad times it drops precipitously. For instance, in the years before the current recession, the industry's production grew at an average annual rate of 2 to 3%. Then when the

Architectural coatings half of production, value in 1982



Total production = 903 million gal

Total value of shipments = $8.3 billion

[a] Original equipment manufacturers. **Source:** Department of Commerce

downturn came, the paint industry as a whole really got socked. Production of paints and coatings, according to government figures, between 1979 and 1982 fell almost 16% to 903 million gal.

Leading the decline were the two main categories of paints—architectural coatings and product coatings, including paint for new autos (so-called original equipment manufacturers or OEM). Production of architectural coatings dropped 21% from 1979 to about 454 million gal in 1982. And product coatings-OEM production declined 19% during that period to 269 million gal in 1982 as production of automobiles hit the skids.

However, not everything was gloomy for the industry during the recession. Special-purpose coatings did reasonably well, with output increasing 8.8% during the period to 180 million gal.

But in spite of the recession and the accompanying downturn in paint production, the value of paint and coatings shipments has increased every year unabated. The value of shipments for all paints and coatings between 1979 and 1982 rose more than 18% to $8.3 billion last year.

Again, special-purpose coatings led the pack with shipments value increasing about 29% from 1979 to $1.7 billion in 1982. Architectural coatings' value rose 18% to $4.05 billion. And the value of product coatings-OEM increased nearly 12% to $2.55 billion.

However, even paint manufacturers themselves do not expect these good times to last long, before paint returns to its more traditional growth patterns. They seem to think that what, since the early days of the recession, has been typified by economists as "pentup demand" probably has just about gone through the system, and paint customers probably will return to normal buying patterns within the next year.

Then, too, for architectural coatings, pentup paint demand, at least on the level of maintenance of older houses, just didn't materialize. According to Robert A. Katherine, chairman of Philadelphia-based McCloskey Varnish Co., many home owners were forced to take two-week layoffs in 1980 and they took the opportunity to repaint their houses. Thus, architectural coatings went into the recession with at least one strike against them—at least some of the houses that would have been painted during the next two or three years already had been done.

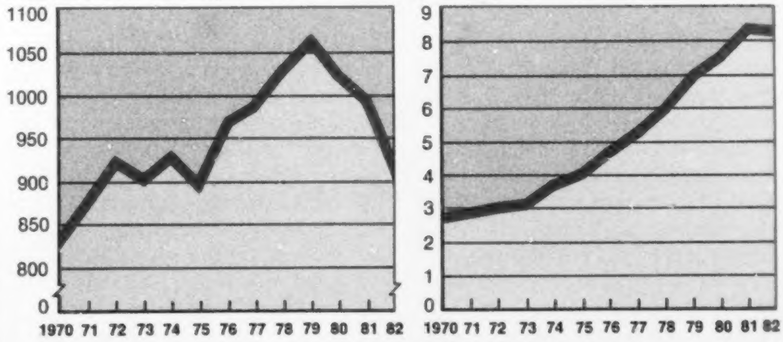
Consequently, architectural coatings demand took a nosedive during the recession. Between 1979 and 1982, shipments of architectural coatings declined 20.4% to 455 million gal. Production dropped 7.3% in 1980, 4.6% in 1981, and 9.9% last year, according to data from the Department of Commerce.

However, in spite of the more than 20% fall in shipments, the value of architectural coatings shipments continued to grow throughout the recession. According to Commerce Department figures, the shipments value of these coatings increased 18.4% between 1979 and 1982. Between 1979 and 1980, shipments value rose 9.3% to $3.64 billion. In 1981 it went up 9.1% to $3.97 billion and, in spite of a very poor economy, continued up 2.0% in 1982 to $4.05 billion.

This means that the value per gallon shipped over the period rose 49.1% to $8.92. The largest increase was between 1980 and 1981, when the value per gallon climbed 20.2% to $7.86. Between 1981 and 1982, the value per gallon increased another 13.5% to $8.92.

Industry managers also worry that federal budget deficits are going to lead to higher interest rates that very easily could slow new housing construction once again, thus causing yet another slowdown in

Paint production growth peaked in 1979, but dollar value has been growing 10% per year for the past decade



Source: Department of Commerce

demand for paints for this market. Also, this once again could affect sales to the automotive industry as higher interest rates drive down demand for new autos.

One thing that producers of architectural coatings have going for them now, other than the upswing in the economy, is the changing taste of the consumer. According to McCloskey's Katherine, right now the trend is toward a more natural look and feel in housing. Thus, purchasers of materials for exterior use are trending away from such things as vinyl siding and aluminum siding and are using paint more. Although this is aiding paint sales at present, it is just as likely that sometime in the future the pendulum will swing again and competing materials once more will eat into traditional paint areas.

One consulting firm that also believes that this trend to a more natural look in housing is probably transitory is Business Trend Analysts, a market research company based in Commack, N.Y. A spokesman for the firm says that with the economy in what is believed to be a sustained period of growth, consumer demand for paint likely will improve as home owners begin maintenance projects that they had put off. The firm projects that sales of architectural coatings in 1983 will increase about 14% to about $3.6 billion.

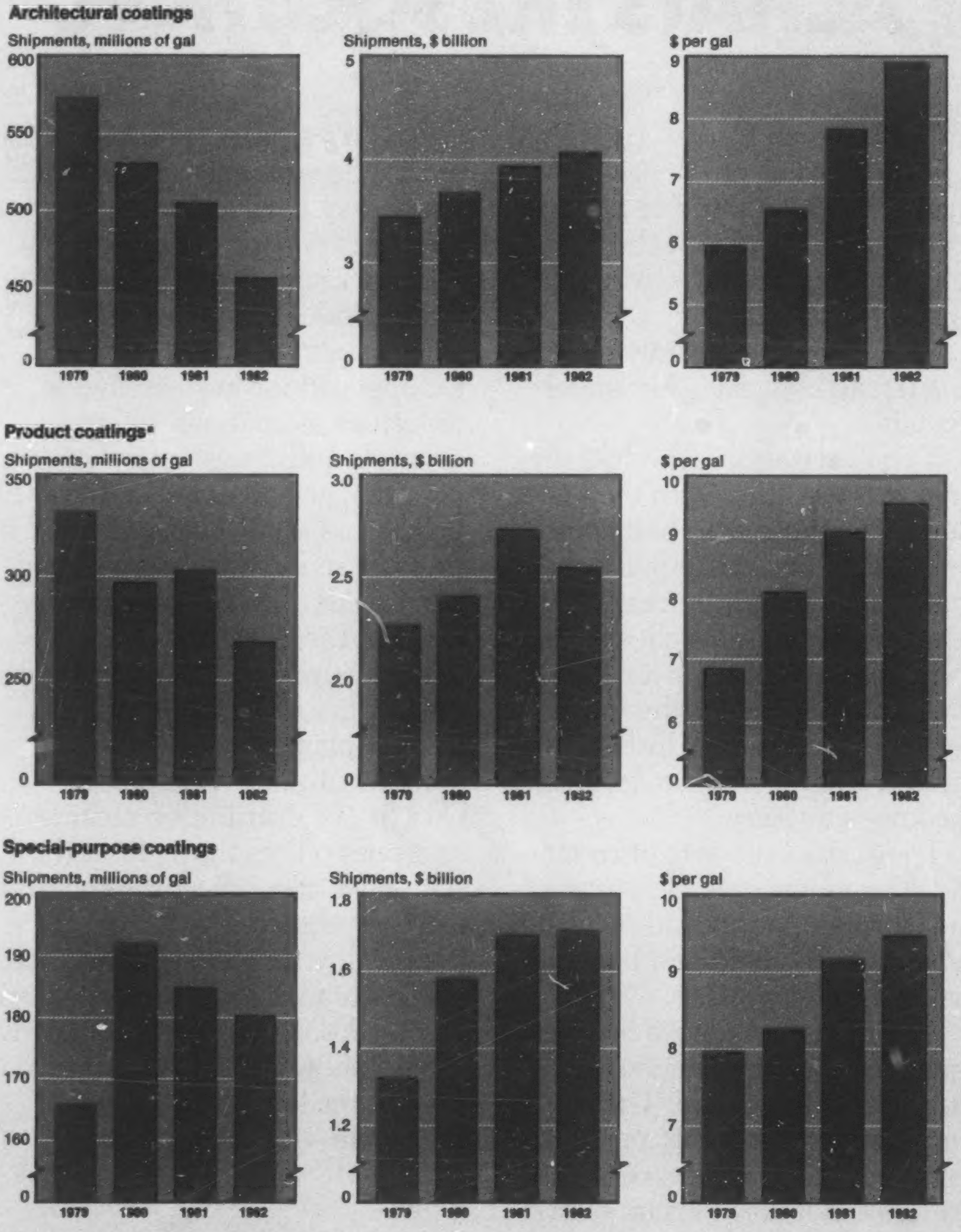
However, the firm says, over the long-term the interior paint market presents better growth opportunities than the market for exterior paints. Exterior paints, Business Trend says, will face increased competition from aluminum and polyvinyl chloride sidings, as well as continued low rates of housing starts

U.S. paint resin producers cover extensive range

	Major producers		
Resins	Captive	Merchant	Merchant and captive
Acrylic	Cook Industrial Coatings, De Soto, Dexter, Grow Group, Inmont, Lilly Industrial Coatings, Mobil, PPG Industries, SCM, Sherwin-Williams		Ashland Chemical, Celanese, Cook Paint & Varnish, Du Pont, H. B. Fuller, Inmont, Reichhold Chemicals, Rohm & Haas, SCM, Union Carbide, Valspar
Alkyd	Beatrice Foods, De Soto, Du Pont, General Electric, Inmont, Lilly Industrial Coatings, Mobil, Benjamin Moore, O'Brien, PPG Industries, SCM, Sherwin-Williams, Whittaker		Cargill, Celanese, Cook Paint & Varnish, McCloskey Varnish, Reichhold Chemicals, Reliance Universal, Spencer-Kellogg
Amino		American Cyanamid, Koppers, Monsanto, Reichhold Chemicals, Rohm & Haas	
Epoxy			
Modified coating	Allied Products, Cook Industrial Coatings, Cook Paint & Varnish, De Soto, Dexter, Guardsman Chemicals, Inmont, McCloskey Varnish, Mobil, M&T Chemicals, O'Brien, PPG Industries, Pratt & Lambert, Schenectady Chemicals, SCM, Sherwin-Williams, Valspar, Westinghouse	AZS, Cargill, Reichhold Chemicals, Spencer-Kellogg	
Unmodified coating			Celanese, Ciba-Geigy, Dow Chemical, Reichhold Chemicals, Shell Oil, Union Carbide
Urethane	De Soto, Du Pont, Inmont, Mobil, Norris Paint, Olin, PPG Industries, Pratt & Lambert, SCM, Sherwin-Williams	ADCO Chemicals, BASF Wyandotte, Beatrice Foods, Cargill, CasChem, Cook Paint & Varnish, Dexter, B. F. Goodrich, Grow Group, Mobay, Morton Thiokol, Polychrome, Reichhold Chemicals, H. H. Robertson, Spencer-Kellogg, Union Carbide, Valspar, Witco Chemical	
Vinyl			
Polyvinyl acetate coating	Bennett's, De Soto, Foy Johnson, Insilco, Kelly-Moore Paint, Benjamin Moore, Norton & Son, O'Brien, PPG Industries, SCM	ADCO Chemical, Air Products, Borden, H. B. Fuller, W. R. Grace, Jones-Blair, McCloskey Varnish, Monsanto, National Starch & Chemical, Reichhold Chemicals, StanChem, Union Carbide, Union Oil, Valspar, Yenkin Majestic Paint	
Polyvinyl chloride coating		Borden, B. F. Goodrich, Occidental Petroleum, Union Carbide	

Sources: Charles H. Kline & Co., SRI International

Although shipments have fallen, value of paints keeps rising



a Original equipment manufacturers. Source: Department of Commerce

Main paint pigments come from diverse group of producers

Pigments	Major producers
WHITE	
Titanium dioxide	American Cyanamid, Du Pont, Kerr-McGee, SCM
Zinc oxide	ASARCO, Fluor, Gulf + Western
COLOR	
Carbon black	Ashland Oil, Cabot Corp., Consolidated Mining & Industries, Du Pont, J. M. Huber, Phillips Petroleum, Sid Richardson Carbon
Iron oxide (black)	Foote Mineral, Mobay, Pfizer, Rockwood Industries
(brown)	Mobay, Pfizer
(red)	Mobay, Pfizer
(yellow)	Mobay, Occidental Petroleum, Pfizer, Rockwood Industries
Lead chromate	Ciba-Geigy, Hydrite Chemical, National Industrial Chemical, Rockwood Industries
EXTENDER & FILLER	
Barium sulfate	Clark & Davies, Thompson, Weinman, Whittaker
Calcium carbonate	H. T. Campbell, Georgia Marble, Manville, Pfizer, Thompson, Weinman
Diatomite	Grefco
Kaolin	Burgess Pigment, Engelhard, Georgia Kaolin
Mica	English Mica, Franklin Mineral Products, General Electric, C. P. Hall
Silica	Illinois Minerals, Malvern Minerals, Tammsco

Sources: Charles H. Kline & Co., SRI International

over the next decade. According to the firm, sales of interior paints will grow at an average rate of about 6.7% per year through 1992, reaching about $2.8 billion in that year. Exterior paint sales, on the other hand, will grow at a lower annual rate of about 5.7% per year, reaching $2.4 billion in 1992.

In fact, even this year, most industry sources C&EN talked with say that interior maintenance seems to be more important to the architectural coatings recovery than is the exterior paint market.

Frost & Sullivan, a New York City-based market research firm, says that between 1982 and 1987, physical volume sales of interior paints will grow about 13%, more than the 11% or so increase forecast for exterior paints over the same period.

The consulting firm says that the fastest growth will be for interior water-based paints, which it expects to grow almost 20% during the period. Frost & Sullivan says that sales of interior solvent-based paints probably will drop about 8% between 1982 and 1987. At the same time, water-based exterior paint sales probably will rise about 16%, with a 2.9% growth for solvent-based exterior paints.

The firm says that growth of solvent-based paints is declining because of government regulations that "have stimulated the industry to develop and produce acceptable water-based paints." The result of the shift is that water-based paints will increase their market share to almost 76% in 1987 from 69% in 1982.

In a survey of retailers, Frost & Sullivan found that they were generally optimistic about paint sales in 1983 and 1984. General merchandise stores and do-it-yourself home centers were the most bullish. The retailers indicated that interior water-based products will continue to be the top-selling products, providing the greatest profit potential for retailers, and providing the best promotional possibilities. Exterior water-based paints ranked second. However, the firm found only minimal gross profit margins for both regular-priced and sale-priced paints.

Concerning past performance not only of paint but of wallpaper and other interior decorating products, the firm says that the consumer has had a limited amount of income to spend on home improvements, and the income normally expended on home decorating projects in recent years has been diverted substantially to energy conservation projects. But because energy improvements are "once in a lifetime projects," consumers probably will be returning to decorating efforts, according to Frost & Sullivan.

The market research company concludes that the improving economic situation likely will help the paint industry post some modest gains in 1984 and beyond, but prospects for major improvements in physical volume growth rates or in profit potential remain slim.

There seems to be at least one other huge impediment to the paint market, and that is the marketing scheme itself for architectural coatings. According to industry sources, the retail market for paint to maintain houses is much more important to them than is the market for paint for new housing. And this paint aftermarket is dominated by some very large outlets that, producers say, will not allow paint prices to rise enough to bring paint margins to the point where they would justify R&D and reinvestment. They say, in particular, that Sears, with its vast number of retail outlets, can pretty much dictate what the price of all paints will be to the consumer. Sources in the do-it-yourself home center industry admit that paints normally are used as loss leaders in their stores to entice customers into the outlets so they will purchase other products. One person in the home center industry says, "We feel that if we can get a woman to bring her husband into a store to buy paint, he will probably buy other items where the markup is better."

Add to this the huge number of producers which make the industry highly competitive and it becomes apparent that low margins are the norm in the paint industry, especially in architectural coatings.

However, in the architectural coatings area, there is a fairly sizable market for maintenance. This is not true in the product coatings-OEM segment of the paint industry where most of the products are original finishes for major durable goods. Consequently, this segment of the industry is even more cyclical than is architectural coatings.

Product finishes are formulated specifically to manufacturers' specifications for products and for methods of application. This includes not only paint, but powders and also lacquers, which go mainly to the wood furniture markets. According to Charles H. Kline & Co., Fairfield, N.J., there are few standard lines of product coatings. The technology is usually proprietary and it is frequently highly sophisticated, especially in the area of automotive and appliance finishes where durability as well as appearance is important.

In the past, solvent systems have dominated the product coatings segment. However, because of environmental and safety regulations, waterborne and other solventless systems likely will take over the lead.

Since product finishes are used for coatings in such highly cyclical durable goods markets as automobiles, boats, aircraft, furniture, and appliances, demand in this segment of the paint market will grow no more than 3% per year in the next several years, according to SRI International, a research firm based in Menlo Park, Calif. Others say that it will pretty much grow at the same rate as the gross national product of the U.S.

In the past four years, product finishes have had an especially rocky road. Between 1979 and 1982 shipments fell 19% to about 269 million gal, according to government figures. However, it was anything but a straight line decline. From 1979 to 1980, shipments fell 10%, then climbed 1.4% in 1981, and fell another 11% in 1982.

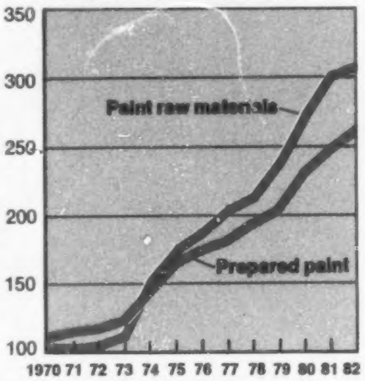
However, the shipments value throughout the period climbed steadily until 1981, then fell in 1982. Between 1979 and 1981, the value of shipments increased 20% to $2.74 billion. But in 1982, shipments value dropped 7.3% to $2.54 billion.

The one thing that did not stop growing during the period was the price of paint. The value per gallon shipped was $6.88 in 1979 and climbed to $9.46 by 1982.

According to Kline, metal finish coatings is the biggest segment of the product coatings market, accounting for about one third of the market. This is followed by automotive and wood finishes, each of which takes about 25% of product coatings production.

Raw material prices have outstripped paint prices

Producer price index, 1967 = 1000



Source: Department of Labor

Kline indicates that there is one other aspect militating against product growth in this area of the paint industry—waste. The efficiency of paint application is extremely important, according to Kline. Currently, the firm says, most of the paint or lacquer used as product finishes is sprayed on. This method has a loss factor of 60 to 65%. This loss factor can be lessened by new forms of application such as electrostatic systems, electrodipping, or using powder systems. However, this elimination of waste will offset any real growth in this industry segment.

The third major area in the paint industry, special-purpose coatings, has applications in new industrial construction and maintenance coatings, traffic paints, automobile refinishes, and metallic finishes. This group also includes aerosol paints. Industrial construction and maintenance is the biggest use, followed by automotive and machinery refinishes.

According to Kline, special-purpose paints and coatings are formulated for special uses or environmental conditions. These include extreme temperatures, chemicals, fumes, and other conditions.

According to government figures, shipments of special-purpose coatings peaked in 1980 at more than 191 million gal, a nearly 16% increase from 1979. In 1981, shipments declined 3.8% to about 184 million gal, followed by a 2.3% decrease in 1982 to 180 million gal.

Again, though, in value of shipments special-purpose coatings continued to increase, even though the increase between 1981 and 1982 was almost negligible. According to Commerce Department figures, in 1980 the shipments value increased about 20% from 1979 to $1.58 billion. They then rose another 7% in 1981 to $1.69 billion, followed by a less than 1% rise in 1982 to $1.7 billion.

Special-purpose coatings were the worst of the three paint industry segments between 1979 and 1982 in terms of value per gallon shipped. Although increasing every year, this unit value managed only an 18% increase for the four years, compared with a 49% increase for architectural coatings and a 38% increase for product coatings-OEM. In 1980, the value per gallon shipped was $8.24 for special-purpose coatings, up 3.1% from 1979. In 1981, the value per gallon climbed 11% to $9.17, followed by a 2.9% increase in 1982 to $9.44.

In spite of the problems of special-purpose coatings in recent years, Business Trends Analysts sees this area as the fastest-growing paint industry segment in the future. The market research firm says that sales will increase nearly 14% in 1983, and that long-term sales growth will average slightly more than 8% per year, bringing sales to about $3.4 billion by 1992.

A big problem for paint producers is that raw material prices have risen much faster than have the paint prices themselves, thus shrinking margins within the industry. According to data from the Labor Department, since 1970 the producer price index for prepared paints has increased 134%, or at an average annual rate of 7.3%, to 263.1 (1967 = 100) in 1982. During the same time, the producer price index for paint raw materials has risen 200% to 304.6, for an average annual growth rate of 9.6%. Much of the raw material price increases resulted from the energy problems of the mid-1970s, because most of paint's raw materials are based on petrochemicals. □

Chemical capacity use rising
Page 6

OCTOBER 10, 1983

CHEMICAL & ENGINEERING

NEWS

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SYNFUELS

After 10 years, no producing industry Page 11

Cover: Airco oxygen unit goes up at Cool Water Coal Gasification Program at Daggett, Calif. Photo by Bill Mitchell

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- **Both OSHA and EPA restrict use of and exposure to ethylene dibromide.** Page 4
- **El Paso Products Co. seems to be on the verge of selling its chemical segment.** Page 5
- **CAS and West German database supplier will connect on-line computer information services in 1984.** Page 5
- **Two new reports published on yellow rain.** Page 5

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World oil prices will fall in the near future but will begin to rise again during the mid-1980s, DOE projects. Page 14

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The Canadian chemical industry is rebounding satisfactorily from a disastrous 1982 and expects to sustain its recovery. Page 17

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Congress seeks to tighten the reins on NIH funding and research, considers legislation to reorganize the institutes. Page 19

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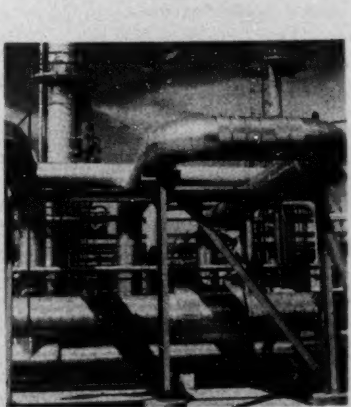


News Focus

Organics are the leaders in boosting chemical plant capacity use as production grows and capacity drops. Page 6

Chemical Plant Capacity Use Accelerates as Organics Lead Way

Revived U.S. economy pushes plant use rate for basic chemicals to 68%, highest in two years, and hikes use rates for plastics to 79%, for synthetic fibers to 85%

William F. Fallwell, C&EN Washington
Bruce F. Greek, C&EN Houston

The chemical industry has eased into a confident upswing following the final shocks of an extraordinarily severe business downturn in the past four years. Recovery has proceeded far faster than expected, even though it has not yet touched all parts of the industry. As a result, the industry may soon have to consider physical expansion in some areas.

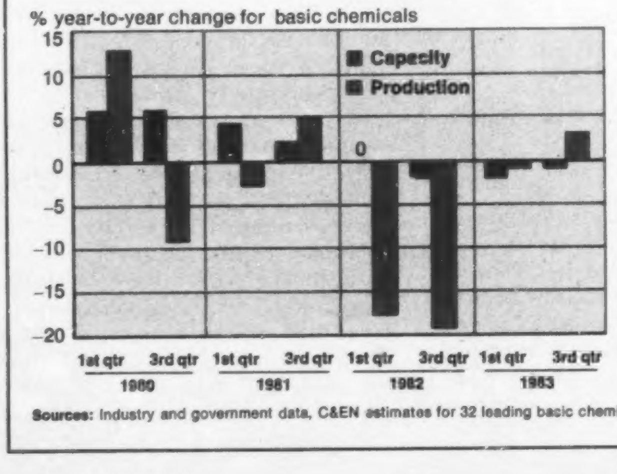
Aside from profits, the key measure in gauging the industry's recovery and in planning the years just ahead is plant operating levels. So far in the 1980s, capacity use has been so low that the industry's main asset moves have been to clean out antiquated plants and drastically upgrade efficiency in surviving units. As a result, most chemical plants can make money at lower use levels than in the past.

So the current rise in plant use rates is doubly meaningful. Although the recovery pace is not the same in all parts of the industry, in the most favored major product areas, organics and downstream polymers, use rates have jumped 10 percentage points or more in just half a year. Inorganics, as usual, lag the pack.

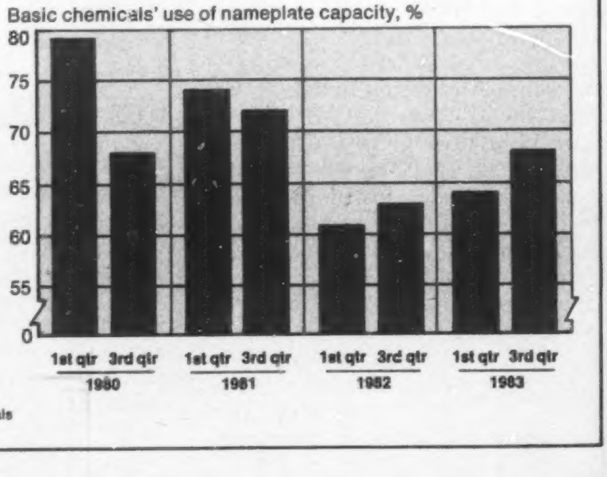
Overall, C&EN's semiannual survey of capacity use in 32 basic chemicals and 11 polymers finds that, from early 1983 to midyear:

- Polymers led the way, with production rates rising to 82% of nameplate capacity from 71%; the low point was 66% in early 1982. Within this group, capacity use rose to 79% from 70% for thermoplastics and to 85% from 71% for synthetic fibers.
- Upstream basic chemicals, trailing polymers as usual, accelerated a slow earlier upturn, with capacity use moving to 68% from 64%; the low point was an unheard-of 61%, also in first-quarter 1982.

Chemical production finally is growing and plant capacity continues to slip . . .



. . . which results in a boost for formerly very low rates of capacity use



Sources: Industry and government data, C&EN estimates for 32 leading basic chemicals

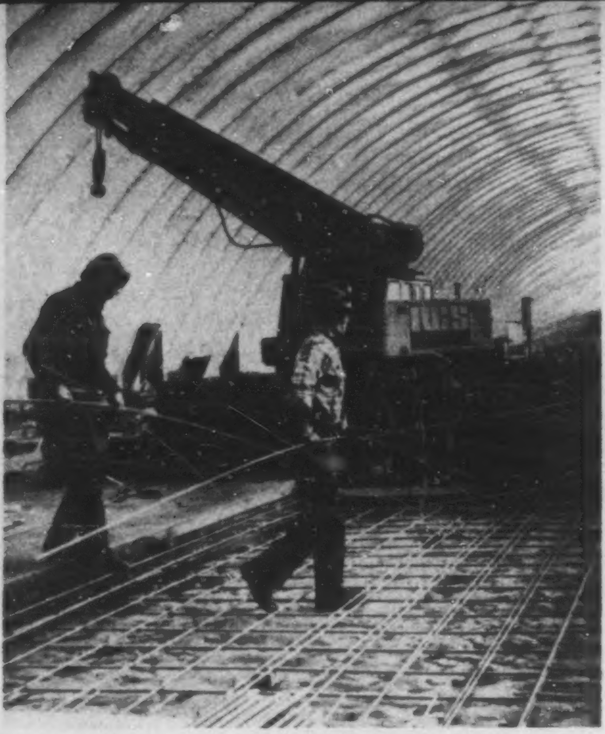
- Plant use rates based on effective capacity (5 to 15% lower than nameplate because of various inefficiencies) shot up to 76% in basic chemicals and 89% in polymers.
- Behind these capacity use data, component production figures are on the way up for most products—2% in basic chemicals and a rousing 15% in polymers.

C&EN's figures underplay the industry's tight capacity management, since they don't delete extensive capacity temporarily shut down until the business recovery reaches higher levels. For example, 15% of ethylene and coproduct capacity could still be down, 25% for ammonia, and lesser percentages for urea, chlorine/caustic, cyclohexane, ethanol, phosphoric acid, phosphorus, sulfur, polyvinyl chloride, and polystyrene.

Effective plant use in basic chemicals pushes up to 76%

Billions of lb per year unless otherwise noted[a]	Third-quarter 1983			First-quarter 1983			Third-quarter 1982		
	Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use		Capacity (nameplate)	Capacity use	
		Nameplate	Effective		Nameplate	Effective		Nameplate	Effective
Petrochemicals—olefins and aromatics[b]									
Ethylene	38.4	74%	82%	39.0	67%	74%	39.0	61%	68%
Propylene (chemical and polymer)	23.0	61	68	23.0	49	54	23.0	56	62
Butadiene[c]	4.5	58	64	4.5	37	41	4.4	40	44
Benzene (bg)	2.3	60	67	2.3	43	48	2.4	48	53
p-**Xylene**	4.9	93	98	4.9	68	72	4.9	60	63
Petrochemicals—C_1 derivatives									
Ammonia (mt)[b]	18.7	64	67	18.7	71	75	19.8	82	87
Urea (mt)[b]	7.8	59	66	7.8	73	81	7.8	72	80
Methanol (bg)	1.8	63	70	1.7	56	62	1.6	76	84
Formaldehyde (37% solution)	9.2	56	59	9.2	55	58	8.9	47	49
Chlor-alkalies									
Chlorine (mt)[b]	14.5	70	74	14.4	67	71	14.6	64	67
Caustic soda (mt)[b]	15.5	66	70	15.4	66	69	15.6	61	64
Soda ash (mt)	10.7	81	85	10.7	74	78	10.9	73	77
Acids									
Sulfuric (mt)	57.5	52	55	57.5	59	62	59.6	49	52
Phosphoric (P_2O_5, mt)[b,d]	12.5	66	69	12.5	71	75	12.6	64	67
Industrial gases									
Oxygen **Nitrogen** } (total, liquid, ttd)	40.0	64	78	37.0	64	78	36.6	65	82
Carbon dioxide (ttd)[e]	19.6	64	70	18.9	61	68	18.4	67	75
Mineral-based inorganics									
Sulfur (total, mmt)[b]	16.0	50	—	15.5	48	—	15.8	53	—
Potash (mt)	2.2	50	—	2.2	86	—	2.7	74	—
Phosphorus (mt)[b]	0.55	67	71	0.55	65	69	0.55	68	72
Plastics intermediates									
Styrene	8.1	77	91	8.2	64	75	8.7	69	81
Vinyl chloride	9.3	79	87	10.1	65	72	10.0	68	76
Toluene diisocyanate	0.70	83	92	0.70	94	104	0.70	76	85
Fiber intermediates									
DMT-PTA[f]	7.6	80	94	7.3	64	75	7.3	56	66
Ethylene oxide	7.3	75	84	7.3	76	84	6.8	67	74
Cyclohexane[b]	3.4	52	55	3.4	31	33	3.1	37	39
Adhesives, coatings intermediates									
Phenol	3.3	83	92	3.6	64	71	3.6	61	68
Vinyl acetate	2.4	83	88	2.4	90	95	2.3	91	96
Pigments									
Carbon black	3.3	73	81	3.3	63	70	3.4	62	69
Titanium dioxide (mt)	0.91	86	100	1.0	60	71	1.0	61	72
Solvents									
Acetone	3.0	67	74	3.3	57	63	3.3	53	59
Ethanol (mg)[b]	240	59	62	240	72	76	240	75	79
Methylene chloride	0.83	71	79	0.83	59	66	0.83	63	70
AVERAGE		**68%**	**76%**		**64%**	**70%**		**63%**	**69%**

a bg = billions of gal, mt = millions of tons, tt = thousands of tons, ttd = thousands of tons per day, mmt = millions of metric tons, mg = millions of gal. b Substantial capacity currently shut down. c Total extraction capacity, which runs about 25% more than basic production capacity. d Includes both wet-process and furnace-process capacity. e Excludes oilfield operations. f Dimethyl terephthalate and DMT equivalents of purified terephthalic acid. **Sources:** Industry and government sources, C&EN estimates



PPG Industries modernizes Natrium, W. Va., chlorine-caustic soda plant to make operation more cost-effective

However, C&EN percentages are undoubtedly closer to reality than six months ago, since many plants have been brought back on stream to feed renewed demand. Also, the recovery pace is widely thought to be moderating from its red-hot level of spring and early summer, so current capacity use might not be much higher than at midyear.

Leading chemical companies commenting on capacity use say that overall averages have hit 70%—between C&EN's averages for basic chemicals and polymers. For example, Du Pont's chemicals hit this point in early spring, and Monsanto is there now.

At one time, such use levels would have meant little or no profit, but not any more. As Monsanto president Richard J. Mahoney told C&EN last month (C&EN, Sept. 26, page 10), "We're running somewhere in the 70% occupancy rate now and we believe we can break even at about 60%. Overall, we used to think the break-even point was somewhere about 75%, and here we are making good money at 70%. I believe there's enough steam in the economy to move those occupancies well up into the 80% levels."

A quick look at C&EN's capacity use score sheets shows the main product areas contributing to these higher overall use averages—and also those still acting as a drag. Plastics and fibers were already on the move in the previous survey (C&EN, May 23, page 7), and they have picked up speed since then. Particularly influential are the two polyethylenes, polypropylene, polyester, and nylon, all of which have moved to more than 80% capacity use. In the best case, a booming carpet market has pushed nylon staple output close to capacity limits.

Both plastics and fibers are enjoying double-digit annual growth in the first year of recovery. Over the past 12 months, production of both the five leading thermoplastics and six main fiber types is up 21%. Growth has been 13% in plastics and 15% in fibers in just the past six months.

In basic chemicals, the good news is that first-stage petrochemicals—the ones made directly from oil or natural gas fractions—have begun to join the recovery. Their plant use rates had sunk so low that they are still below the average for basic chemicals, but they are on their way. Basic olefins and aromatics covered in the

Plant use tops 80% in the leading commercial polymers

	Third-quarter 1983			First-quarter 1983			Third-quarter 1982		
	Capacity	Capacity use		Capacity	Capacity use		Capacity	Capacity use	
Billions of lb per year	(nameplate)	Nameplate	Effective	(nameplate)	Nameplate	Effective	(nameplate)	Nameplate	Effective
PLASTICS									
Polyethylene, low density	10.1	81%	86%	10.1	74%	79%	9.3	76%	81%
Polyvinyl chloride[a]	8.9	71	83	8.9	55	64	8.4	59	69
Polyethylene, high density[b]	6.3	94	99	6.3	85	89	6.1	82	86
Polypropylene	5.1	86	96	5.1	83	92	5.1	61	68
Polystyrene[a]	5.3	64	75	5.3	55	65	5.3	60	71
AVERAGE		**79%**	**88%**		**70%**	**78%**		**68%**	**75%**
SYNTHETIC FIBERS									
Filament yarn									
Polyester	1.6	88	93	1.6	83	88	1.6	76	81
Nylon	1.9	84	90	1.9	64	68	2.0	64	68
Olefin	1.1	71	75	1.0	48	51	0.99	60	64
Staple									
Polyester	2.7	89	95	2.7	75	80	2.8	62	66
Nylon	0.99	96	102	0.98	81	86	0.99	76	81
Acrylic	0.83	83	88	0.83	77	82	0.84	82	87
AVERAGE		**85%**	**91%**		**71%**	**76%**		**70%**	**75%**
OVERALL AVERAGE		**82%**	**89%**		**71%**	**77%**		**69%**	**75%**

a Between 5 and 10% of this capacity shut down. b Excludes 500 million lb new capacity starting up. **Sources:** Industry sources, Society of the Plastics Industry, Textile Economics Bureau, C&EN estimates

C&EN capacity use indicator: the ground rules

Capacity use at chemical plants is difficult to measure and requires certain assumptions. These bring some order to the maze of variables affecting this critical indicator of the industry's health.

With the help of industry and government sources, C&EN measures capacity use as a percentage of both nameplate and effective maximums. Nameplate capacity is the official design capacity of plants. Effective capacity is the practical maximum after reductions for unplanned maintenance, corrosion problems, changes in product mix, and other influences. Although engineering companies and industry statistics groups try to make nameplate capacity data as real as possible, practical problems almost always reduce effective maximums to 85 to 95% of the official totals. For short periods, plants can run more than 100% of effective top capacity, but such a rate doesn't last more than a few months.

Capacity use is given over as much of a calendar quarter as production data permit, with no seasonal adjustment. The figures are for plants actually operable. At present, some products such as ethylene, ethanol, chlorine, polystyrene, ammonia, and urea have plants temporarily shut down because of weak markets. These plants still are included in capacity totals. The totals exclude new plants just starting up and old plants out of operation for long periods because of accidents. As much as possible, capacity figures stay current with expansions.

Capacity data don't take into account other temporary fluctuations for fuel and electric power interruptions, equipment failure, and feedstock scarcity or substitution. The feedstock variables, for example, have been important in the past few years in ethylene production, altering maximum output for several coproducts such as propylene, butadiene, and benzene.

Products in C&EN's capacity use survey are the same as those in the Key Chemicals and Key Polymers series. These are the core products of the industry, the building blocks leading to downstream production of thousands of more specialized products.

C&EN survey—ethylene, propylene, butadiene, benzene, and *p*-xylene—have reached 69% of nameplate capacity, up from 53% in early 1983.

The natural gas-derived C_1 derivatives—ammonia, urea, methanol, and formaldehyde—haven't moved as much in plant use, rising only to 66% from 64%. The root of the trouble is the principal market still holding down the whole chemical industry—fertilizer. Fertilizer is finishing a wretched year but could perform much better in 1984 as farm income starts to rebound. So ammonia and urea could get some relief. For methanol and formaldehyde, the refreshed housing market has been a boost, but formaldehyde has taken a beating in some markets because of suspected safety problems.

Fertilizer also has had a hand in delaying recovery for four leading inorganics. Sulfuric and phosphoric acids depend so heavily on farm markets that their capacity use, alone among major categories, has fallen in the past half-year—to a combined 59% in the third quarter from 65% in early 1983. For the same reason, potash capacity use has tumbled to barely 50% from 86%. And sulfur capacity use has stayed very low, about 50%.

The two other major inorganic groups haven't done much better. Chlor-alkali analysts are happy that chlorine plant use has regained 70%, the best since 1981, but that's historically very low for chlorine and isn't up much from 67% in the first quarter. Also languishing are the major industrial gases—oxygen, nitrogen, and carbon dioxide—whose overbuilt capacities are operating at 64%.

The picture brightens in three classes of organic intermediates. Major plastics intermediates—styrene, vinyl chloride, and toluene diisocyanate—have felt the strength downstream and are all close to 80% in capacity use, up from an average of 74% six months ago. Styrene and TDI have moved over 90% in effective capacity use, and their supplies are considered to be tight.

Not quite so strong, the leading fiber intermediates—dimethyl terephthalate/terephthalic acid, ethylene oxide, and cyclohexane—still have climbed to 69% capacity use from 57% early in the year. Biggest percentage gainer of these is cyclohexane, whose plant use zoomed to 52% from 31% in the latest six months to supply booming nylon. But DMT/PTA wasn't far behind, with plant use rising to 80% from 64%. Ethylene oxide actually slipped to 75% from 76% because of a sluggish antifreeze (nonfiber) market.

In the adhesives and coatings intermediates, vinyl acetate moved over 80% plant use and phenol staged a dramatic upturn, rising to 83% from 64% early in the year. Although the rise is genuine, based on the big gain in phenol's housing market, it is levered by a cut in estimated plant capacity. A major capacity shakeup is due to phenol this fall as Monsanto shuts down 500 million lb per year at Alvin, Tex., and Allied restarts 500 million lb of capacity at Frankford, Pa. The capacity total of 3.3 billion lb won't change.

A companion shift will occur in coproduct acetone capacity at Monsanto and Allied, involving 300 million lb per year on both sides. Since Shell and Exxon have closed isopropyl alcohol-based acetone units, C&EN's capacity estimate is now 3.0 billion lb, down from 3.3 billion in early 1983. Capacity use in the solvent has moved up to 67% from 57% in the past six months. In other solvents, methylene chloride has joined the recovery with a plant use increase to 71% from 59%. But sagging synthetic ethanol, beset with competition from fermentation ethanol, has slumped to 59% from 72%.

The remaining major product area, pigments, has benefited nicely from the business recovery. As expected, titanium dioxide has moved toward new prosperity, with plant use jumping to 86% from 60% last winter. One statistical aid was a 9% drop in estimated capacity owing to a plant closing. Carbon black hasn't reached this stage of recovery, but capacity use has climbed to 73% capacity from 63%. □

Oleochemicals Fashion Long-Term Optimism from Near-Term Gloom

Producers believe that improved crop yields and eventual higher oil prices will make their products more competitively priced

Patricia L. Layman, C&EN London

When an industry is facing such problems as steeply rising prices of its raw materials while the prices of competing materials slump, and intensifying competition on a worldwide basis is shaking up the industry's basic structure, it might be excused for some gloom. But even with problems such as those facing the oleochemicals industry, it remains surprisingly optimistic.

Oleochemicals marketers, in fact, believe that in the long run, improved crop yields and plantings will help bring down prices that are now off on a cyclical spurt. They believe that, assuming the oil glut will not be permanent and so will someday end, there will be a concomitant end to the present low prices of major petrochemical feedstocks. Moreover, as specialty oils from now-exotic oilseed crops become more important for specific end-use applications, there is a possibility that growers or crushers can contract directly with customers, getting away from the volatile world of the commodities market.

And perhaps more important as a reason for optimism is that the industry is so diverse, with few end uses having a significantly high share of the total market. Enough of those end uses individually have healthy growth prospects that the overall industry stands to benefit once the economy starts moving again.

To some extent, the very diversity of the industry has been a problem for it. Some in the industry, for example, speak somewhat defensively of "the invisible industry." The American Oil Chemists' Society used that expression, in fact, when it set up its first world conference on oleochemicals in Montreux, Switzerland, late last month. Some 90% of the world's annual production of roughly 60 million tons of animal and vegetable fats and oils is consumed in edible products. That dwarfs the remainder, which goes into oleochemicals, for eventual incorporation into consumer products such as cosmetics and detergents, or industrial formulations for mining, plastics processing, printing inks, transportation, and a host of other fields.

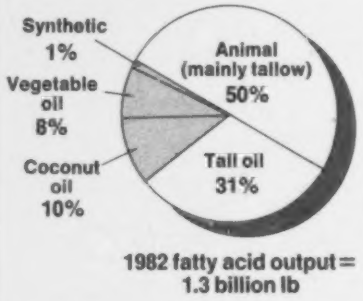
Probably the most striking feature of the oleochemicals industry today is its often-fierce competition with the petrochemicals industry. Actually, at times, there is little true competition. For fatty acids, for example, petrochemicals make up only 1.2% of the total raw-material sources. And fatty acids are by far the largest segment of the oleochemicals industry, accounting for nearly 59% of the total business.

However, with other product areas, petrochemicals make up a far more significant share of the market. In the production of alcohols for detergents, for example, petrochemically based alcohol probably accounts for nearly 85% of the total; as late as the early 1960s, detergent alcohols were almost exclusively derived from natural fats and oils.

Few other areas show such decidedly lopsided balances. But the two raw materials industries nevertheless abide in a somewhat nervous but courteous coexistence, as customers swing back and forth in response to raw material price fluctuations.

At present, pricing is being influenced most heavily on the petro-

Tallow, tall oil yield most U.S. fatty acids



1982 fatty acid output = 1.3 billion lb

Source: Humko Chemical

U.S. oleochemicals market is dominated by fatty acids

Millions of lb	1982	1977	1968	1982 sales ($ millions)
Fatty acids	1300	1279	916	$ 455
Natural fatty alcohols	150	140	120	97
Natural crude glycerine	125	178	213	79
Surfactant esters	250	226	164	228
Fatty amines, amine oxides	307	261	156	255
Fatty alkanolamides	60	81	57	46
Other fatty amines	23	23	15	24
TOTAL	2215	2188	1640	$1184

Sources: Humko Chemical, C. H. Kline & Co., U.S. International Trade Commission

Competition is changing the fatty-acids roster

Acme Hardesty Co.[a]
Arizona Chemical
Armak Co.[b,c]
Ashland Chemical Co.[c]
Capitol City
Crosby Chemicals[c]
Darling & Co.
Emery Industries[c]
General Mills[b,c]
Glyco Chemicals
A. Gross & Co.[c]
Humko Chemical[c]
Hercules
Pacific Vegetable Oil Co.[a]
Petrochemicals[c]
Procter & Gamble
Reichhold Chemicals
Sylvachem Corp.
Union Camp Corp.
Westvaco Corp.

Note: U.S. producers, 1974–83. a No longer a producer. b No longer in merchant fatty acid business. c Changed ownership 1974–83. Source: Humko Chemical

chemicals side by the current abundance of oil that is forcing crude oil prices down, helping to keep petrochemical prices down. It hasn't always been that way. Following the Arab oil embargoes, for example, the price of ethylene, among others, began a steady rise, and at one point became more expensive than tallow, soybean oil, and coconut oil.

At that time, soy and coconut oils were both showing price decreases, reaching decade lows in 1982. Since then, however, prices have started up with news of crop failures in the U.S.S.R., and drought-damaged crops in many other parts of the world. Some oleochemicals producers, for example, feel that official estimates for soybean crops in the U.S. of 1.55 billion bushels is unrealistically optimistic. More likely, they predict, are yields of only 1.3 billion bushels or even 1.2 billion bushels.

Such a dramatic decrease in soybean yields will mean stress on other oilseed crops. Most of the pressure will be for edible uses; the "invisible industry" of oleochemicals unfortunately doesn't pack that much clout in comparison. It will also mean higher grain prices for animal feed—so more animals will be slaughtered. For the short term, that will be good news for tallow purchasers, but longer term, the prices will go up as there are fewer animals to keep the tallow supply constant.

Given their historical vulnerability to natural disasters, weather problems, crop failures, and so on, suppliers of fats and oils are working to tackle the situation in several ways. One simple way: Increase the crop plantings. Oleochemicals marketers are fond of pointing out that their feedstocks are renewable resources, and indeed, the Far East, in particular, is renewing resources at a smart clip. In Malaysia, palm oil already has outstripped natural rubber as a key export. Exports of palm oil are predicted to hit 3 million metric tons this year, compared with 2.8 million in 1982. (Natural rubber exports are expected to be 1.51 million metric tons this year.) An additional 500,000 metric tons of palm oil were consumed within the country. Total Malaysian palm oil production is expected to climb to 4.3 million metric tons in 1985, and 6.5 million by 1990.

Meanwhile, Canadian crushers are boosting their production of rapeseed oil. World production of rapeseed oil in 1981 was 3.8 million metric tons; that is expected to climb to 7 million by 1990, by far the fastest-growing oil. By contrast, world production of soy oil, 12.2 million metric tons in 1981, is expected to hit 15.9 million, and output of tallow is expected to grow from 6 million to 7.2 million metric tons by 1990. Coconut oil production is forecast to grow from 1.5 million metric tons in 1981 to 3 million metric tons by 1990.

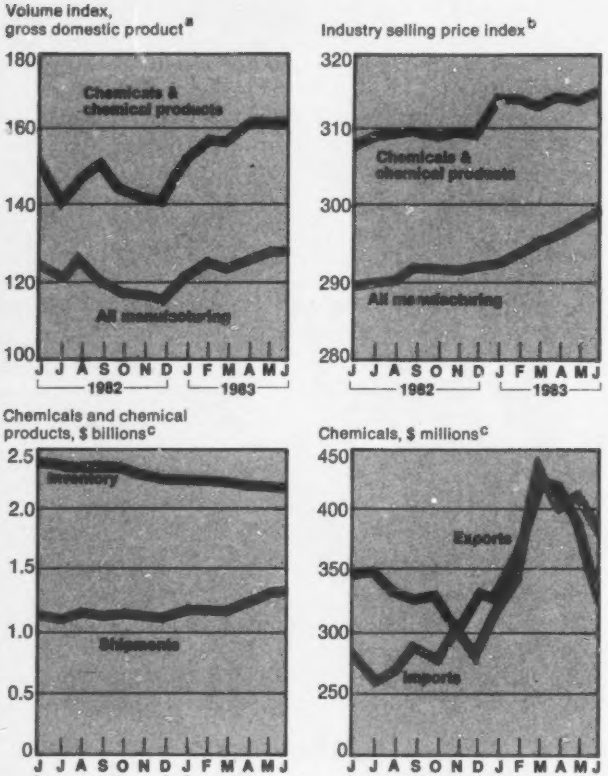
To some extent, the naturally derived fats and oils are interchangeable. But each has some characteristics that make it more suitable for some uses than for others. For example, Henkel marketers noted at the Montreux oleochemicals conference that rapeseed oil has a high proportion of long-chain components that make it especially attractive for conversion into fatty alcohols, for example, for further modification into oilfield chemicals and synthetic lubricants. Similarly, palm-oil characteristics can lead it into serious competition for markets in the oleochemicals market, predicts Colin A. Houston, a consultant in Mamaroneck, N.Y., who is embarking on a study of the oil.

One of the key determinants in what happens to the fats and oils industry, many marketers believe, will be the impact of new technology on both processing and crop yields. For example, it could be something as basic as developing clays that can quarter the time for hydrogenation of the oils and fats, or the exotic promise of enzyme splitting and genetic manipulation of oil-producing crops. Houston, for instance, predicts that "future gene manipulation techniques will provide the tools to alter the chemical structure of the oils produced from palm."

According to M. K. Schwitzer, an oleochemicals consultant in London, already "a beginning has been made to replace existing chemical processes by biotechnological techniques such as algal oil and glyceral production, enzymic fat splitting, and the preparation of cocoa butter replacers."

And agriculture researchers are working hard to give the oleochemicals industry even more raw materials to play with. The U.S. Department of Agriculture, for example, has a major research program to identify new oilseed crops, according to Lambertus H. Princen, assistant director of USDA's northern regional research center in Peoria, Ill. Not only are the crops potential sources of oil, "we've found all sorts of unique acids in seed oils," Princen says, with various epoxy and keto groups, mixtures of chain lengths that range from eight to 12 carbons to others of 20 to 28 carbons. Crambe is a potential winner, USDA feels, as is cuphea, another oilseed crop. And raising high hopes in a startling wide swath of the world, from the U.S. Midwest to New Zealand, is the orange roughy, a fish recently discovered in New Zealand waters that is being touted both for its flesh, as a piscatorial delicacy, and as a source of oil. □

Canada's chemical industry is bouncing back



a Seasonally adjusted, 1971 = 100. b 1971 = 100. c Canadian dollars.
Source: Statistics Canada

Chemical output: still a few weak spots

Production, thousands of metric tons	1982	Seven months 1982	Seven months 1983	% change 1982–83
ORGANICS				
Ethylene	1013	545	678	24.5%
Propylene	618	391	415	6.2
Benzene	504	300	328	9.3
Toluene	470	259	239	−7.7
Xylene	396	243	237	−2.8
PLASTICS				
Polyethylene, total	571	336	338	1.0
Polyvinyl chloride	194	118	140	18.7
INORGANICS				
Hydrochloric acid	135	77	93	19.9
Nitric acid	977	596	482	−19.1
Phosphoric acid[a]	503	359	354	−1.4
Sulfuric acid	3131	2024	1971	−2.6
Ammonia, anhydrous	2509	1502	1616	7.6
Ammonium phosphate	888	655	719	9.9
Chlorine	1233	735	771	5.0
Sodium hydroxide	1367	816	856	5.1

a 100% P_2O_5. **Source:** Statistics Canada

The Canadian economy, which followed that of the U.S. into recession, is following it back into recovery. Business conditions in Canada may not be all that everyone would like, but they are immeasurably better than they were a year ago. What's more, this recovery appears to be sustainable and likely to continue throughout the rest of 1983 and into next year. And, after last year's economic fiasco, this recovery is unashamedly welcome.

For Canadian chemical companies, the recovery is particularly welcome. Last year, the petrochemical sector lost $129 million (Canadian), its worst loss on record and a dramatic reversal from the $198 million net profit chalked up in 1981. Inorganic chemical companies retreated to profit levels of 1975; those in the organic and specialties chemicals segment suffered drastic drops in profits.

This year, Canada's chemical industry is riding the country's economic resurgence back to profitability. But the recovery has not permeated all chemical industry segments equally. Not yet, anyway.

At midyear, for instance, output of medicinals and pharmaceuticals had not yet bounced back to year-ago levels. Some of the heavy inorganic acids still are struggling. Aromatics output still is slow.

For too many products, plant operating rates are not yet up to comfortable levels. Selling prices are up, but not as much as some producers would like to see. Output of many major commodity chemicals, although running ahead of last year's anemic pace, have not yet reached 1981 levels.

However, Canadian chemical companies no doubt will benefit from several encouraging developments. The auto and construction industries are perking up. And most chemical companies, forced by last year's recession to trim excess fat, are in good shape to profit from the economic upturn.

In general, the Canadian chemical industry is outpacing the all-manufacturing average in the race toward recovery. Output is running about 8% ahead of last year's pace, with some specialty areas such as paints and soaps showing particular strength.

In Canada's all-important petrochemical industry, ethylene output is improving dramatically. Production is running about 25% above last year's levels, helped by a 19% boost in production of polyvinyl chloride. Polyethylene, however, still is sluggish.

Exports, also critical for Canada's chemical industry, are not faring so well as companies would like. Through the first half of the year, chemical exports were up only 4%, whereas imports have increased 17%. These imports, of course, reflect Canada's surging economy, but exports still must contend with foreign economies that have not recovered fully from the recession.

Meanwhile, Canadian chemical leaders are happy with the healthier business climate they already are enjoying. Canadian economists see a 3% improvement in gross national product this year and an even better 5% advance in 1984. This outlook should enable the industry to improve plant operating rates, push through some much-needed price increases, and write their financial reports in black, rather than red, ink.

Earl Anderson, New York

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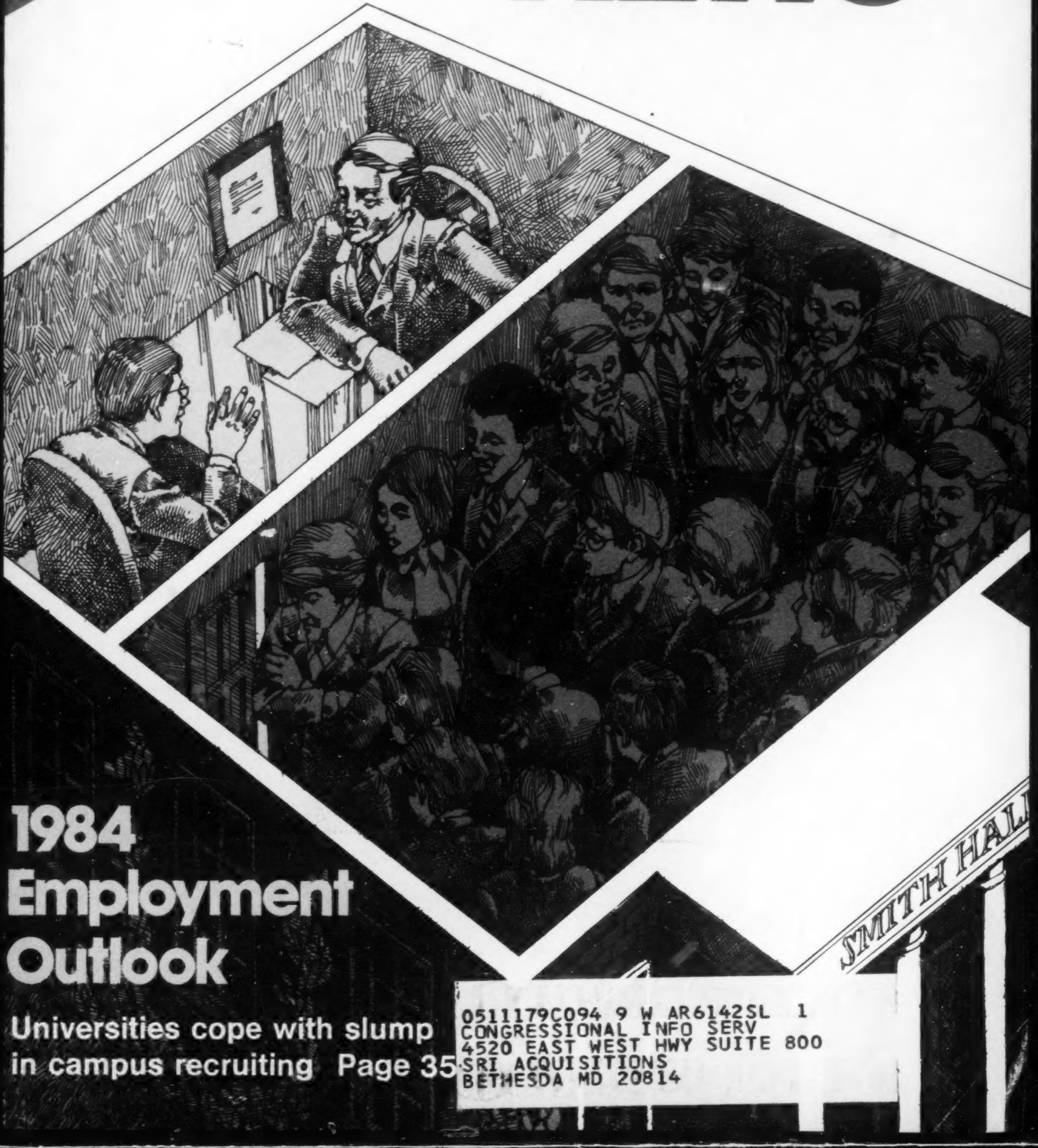
Pacific Rim chemicals market is promising but frustrating Page 9

OCTOBER 17, 1983

CHEMICAL & ENGINEERING NEWS



1984 Employment Outlook

Universities cope with slump in campus recruiting Page 35

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Cover: Drawing by John Heinly

CHEMICAL & ENGINEERING NEWS

Volume 61, Number 42
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OCTOBER 17, 1983

News of the Week

- **Chemical stocks have been outperforming record-setting Dow Jones Industrials during the past few months.** Page 6
- **MIT scientists duplicate important step in expression of genes.** Page 7
- **Lapse of export law may lead President to invoke emergency powers act and spur Congress to rewrite the law.** Page 7

Business

Nations on the Pacific Rim seem ripe for more U.S. chemical ties but, even though their economies are growing more rapidly than those of the West, they do pose risks for investors. **Page 9**

Government

Both NSF and the White House OSTP suffer from lack of personnel; failure to fill key posts may cause budget difficulties. **Page 15**

Technology

Aerospace giants as well as small firms aim at commercializing space with help from NASA, approval of Administration. **Page 20**

Oxidative methylation process, developed in the U.S.S.R., could lead to C_1 process to make acrylonitrile. **Page 29**

Science Policy

Council for Chemical Research shows progress in industry support of academic research but funding problems loom. **Page 33**

Books

"The Science in Science Fiction" by Peter Nicholls discusses the different concepts of "science" in science fiction. **Page 57**

1984 Employment Outlook

Chemical and engineering graduates found a tight job market, lower salaries but the outlook is improving. Page 35

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STOCK MARKET RALLY: Chemicals outperform top indicators

Chemical stocks have risen faster than most indexes in past year

	Oct. 7, 1983	Oct. 8, 1982	% change
Dow Jones Industrial Average	1272.15	986.85	28.9%
New York Stock Exchange Composite	98.72	75.00	31.6
New York Stock Exchange Industrials	115.04	85.14	35.1
American Stock Exchange Index	232.27	149.57	55.3
Over the Counter Composite	297.36	198.89	49.5
Over the Counter Industrials	353.47	226.01	56.4
Standard & Poor's 500	170.80	131.05	30.3
Standard & Poor's 400 Industrials	192.36	146.21	31.6
C&EN Chemical Stock Index[a]	191	295	54.5

[a] C&EN index based on stock prices for Allied Corp., American Cyanamid, Celanese, Dow Chemical, W. R. Grace, Monsanto, and Union Carbide.

In the past few months, while the Wall Street spotlight has been on the broad Dow Jones Industrial Average and the record highs that it keeps setting, chemical stocks have done even better. In fact, C&EN's chemical stock index has vastly outperformed the Dow Jones Industrial Average over the past year. It means that Wall Street rates chemical earnings very high for 1984.

In the past three months, chemical stocks as measured by C&EN's index have risen faster than any of the standard market indicators, more than doubling the pace of the Dow Jones average.

In spite of some relatively dire predictions about an October correction in the stock market, recent events indicate that the climb will continue. The market seems to have gotten over much of the volatility that characterized it just a few months ago, when almost any kind of economic news caused sharp ups or downs. Now the market just ignores bad news.

Although growth in market indexes, including C&EN's, has slowed since early summer (C&EN, July 18, page 7) on an annual basis, most indexes still are going strong. The chemical index is near the top of the pack. Between Oct. 8, 1982, and Oct. 7, 1983, C&EN's index climbed 54.5% to 295 (1954 = 100).

This performance was exceeded by only two of the broader market averages—the American Stock Exchange Index and the Over the Counter Industrial Index. The American Stock Exchange Index increased 55.3% to 232.27 during the same period, and the Over the Counter Industrial Index shot up 56.4% to 353.47.

However, since early summer, chemical stocks have outperformed all the broader indexes. Security analysts have talked about a "flight to quality" over the summer to explain the rapid rise in the Dow Jones average. In the three months ending Oct. 8, the Dow Jones Industrials increased 5.4% to 1272.25 to lead all of the standard indexes. However, C&EN's chemical stock index jumped 13.9% in that time. Some stock indexes such as the Amex index and both of the OTC indexes actually have fallen in the past three months.

For instance, the American Stock Exchange Index has fallen 5.5% to its present 232.27 from the first week of July. The Over the Counter Composite has dropped 7.0% to its current 297.36 from the first part of July. And the Over the Counter Industrial index has fallen more than 10%—10.7% to be exact—since July to 353.47.

The rest of the indexes rose, but their increase was not even enough to match the DJI. The New York Stock Exchange Composite went up 1.9% to 98.72. The New York Stock Exchange Industrials rose only 1.3% to 115.04. The broad Standard & Poor's 500 index increased 2.2% to 170.80, while the Standard & Poor's 400 Industrials increased just 2.0% to 192.36.

If security analysts are correct in their standard thesis that the stock market predicts earnings about six months in advance, the runup of the chemical stock index during the summer bodes well for chemical earnings in 1984. And Wall Street does seem to be banking on high chemical profits next year. For example, Richard A. Derbes, chief chemical analyst for Oppenheimer & Co., a New York City investment firm, says that several indicators of overall economic activity "suggest an environment in which the demand for chemicals rises substantially, enabling high enough overall sales and margins to produce robust profits."

Oppenheimer thinks many chemical firms will have record gross margins in 1984. Some firms, Derbes says, are already exhibiting record results. Consequently, he adds, "we believe the profit recovery of the next year will continue to be very robust even if the economic recovery is somewhat disappointing."

How can chemical profits do so well in a tepid recovery? Because chemical firms' drastic efficiency moves of recent years allow good profitability at lower rates of plant capacity use. This realization has seeped through Wall Street analyses and is a large factor in the recent bid-up of chemical stock prices. □

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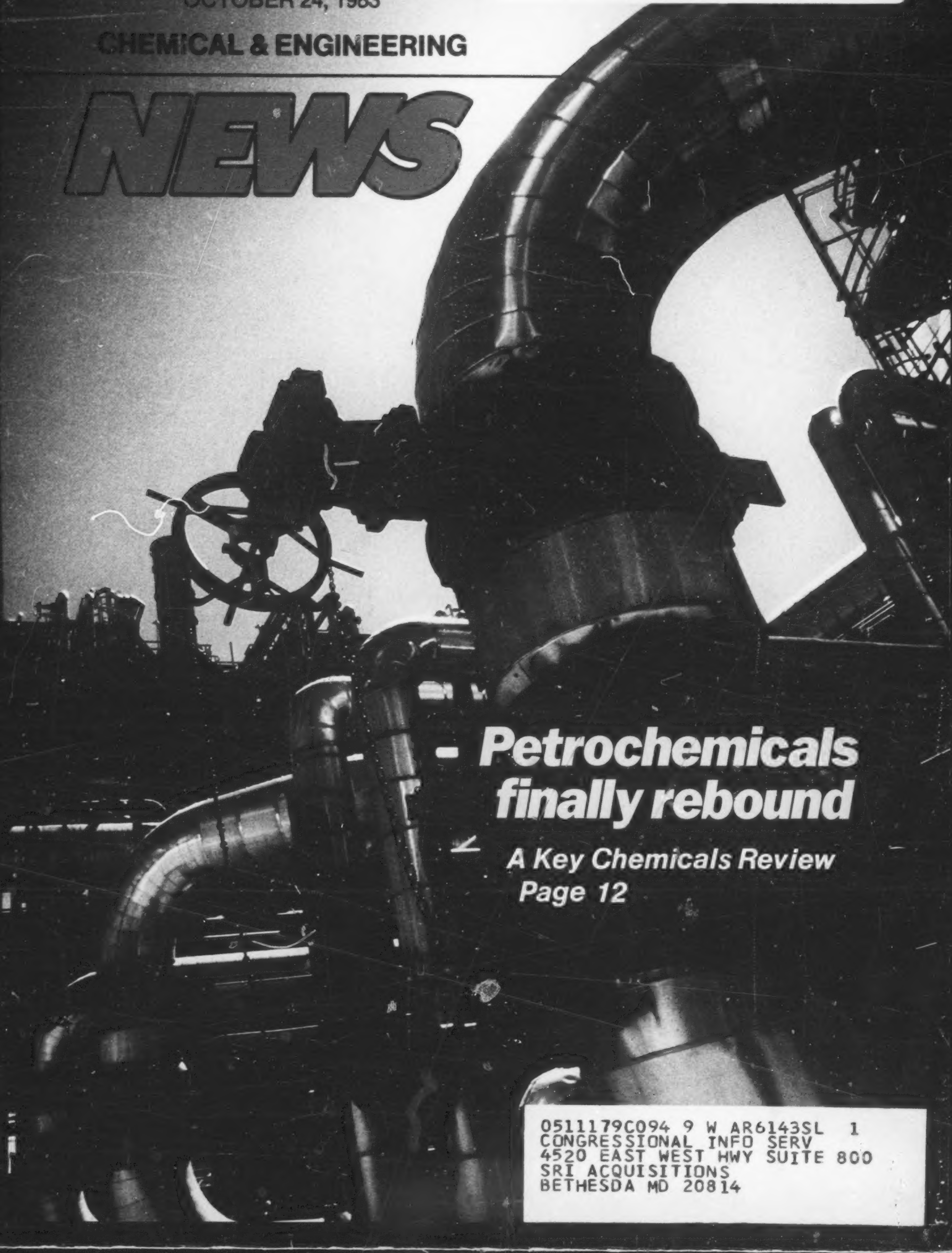
OCTOBER 24, 1983

CHEMICAL & ENGINEERING

NEWS



Petrochemicals finally rebound

A Key Chemicals Review
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Cover: Arco Chemical's olefins and aromatics complex at Channelview, Tex.

CHEMICAL & ENGINEERING
NEWS

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OCTOBER 24, 1983

News of the Week

- **U.S. makes a clean sweep; all of the 1983 Nobel science prizes go to Americans.** Page 4
- **Dow Chemical requests that its registrations for the use of two of its herbicides be canceled.** Page 5
- **Du Pont signs letter of intent to sell most of its Conoco Chemicals unit.** Page 6
- **Creationism issue heats up again with a split decision in the Louisiana Supreme Court.** Page 6
- **Genetic engineering paves the way for New York scientists to prepare a herpes vaccine.** Page 6

Business

U.S. basic olefins and aromatics climb toward financial health; further gains are expected in 1984. **Page 12**

Consumption of antioxidants in U.S. is estimated to grow to 44 million lb in 1986, marking significant recovery from 1981. **Page 18**

International

Canadian excess liquefied petroleum gas eyed as a potential feedstock for some higher olefins. **Page 19**

Government

Cleanup costs of hazardous waste sites get guidelines; EPA defines criteria for determining who pays what and how much. **Page 22**

Science

Interplay of pollutants in troposphere, the focus of intense study by NOAA team, is beginning to be unraveled. **Page 24**

Technology

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Basic Petrochemicals Swing into Long-Awaited Recovery

Doing much better in 1983 than forecast, basic olefins and aromatics head toward another solid gain in 1984; some supplies could get snug

Bruce F. Greek, C&EN Houston

U.S. petrochemicals are finally on the move again. These long-suffering big-volume organics produced tanker loads of red ink for their owners in the early 1980s but now are well on the way toward financial health. They have outstripped most forecasts for this year and seem certain to make further gains in 1984.

Production growth for the five major petrochemicals covered in the following pages—ethylene, propylene, butadiene, benzene, and *p*-xylene—reached double-digit numbers year-to-year in the second and third quarters after a slow start in the first. Production is not yet back to the old highs, but it is headed that way. For example, new highs are due for ethylene and propylene in 1984.

Even though production growth has slowed since early summer, the upward tilt is expected to continue through 1984. Demand growth has slowed, too, but is still fairly strong—possibly at a more sustainable level.

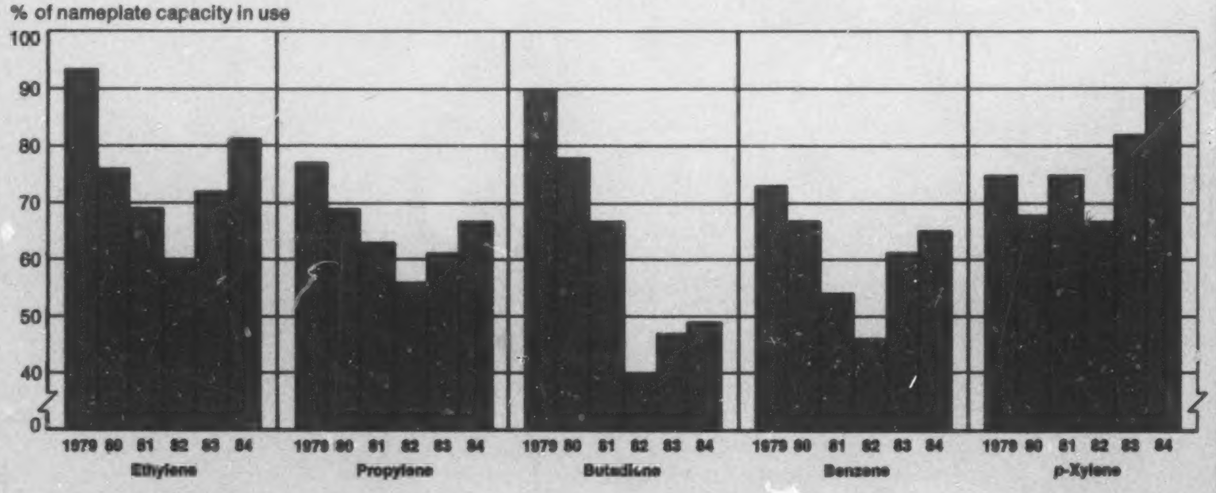
Key Chemicals

Overall performance for the five leading petrochemicals has been a surprise for analysts, who generally feared just a 5 to 10% output gain this year over the very poor showing in 1982. Instead, combined production for the five chemicals is jumping 15%, from 51 billion lb to nearly 59 billion lb. Value of production is up even more because of higher prices. Estimated combined value in 1983 will exceed $12.5 billion, up almost 20% from 1982. These estimates assume no disruption in world oil supplies from the Iran-Iraq war.

By present forecasts for 1984, combined production of these petrochemicals could move up another 9% to 64 billion lb, close to the old production record in 1979. Production value, including estimates for selling price increases, could be up 13.5% to more than $14 billion—again, close to the all-time high in 1981.

After such performance, producers still will have considerable unused capacity but may have to think over expansion plans earlier than expected in a few cases. The most obvious is *p*-xylene, which is virtually guaranteed a snug market in 1984. Ethylene coproducts, especially propylene, may need a look, too, by the mid-1980s if the trend continues toward light feedstocks, which tend to curb coproduct production.

Plant-use rates will head up substantially as recovery rolls into 1984



Sources: Industry and C&EN estimates; International Trade Commission

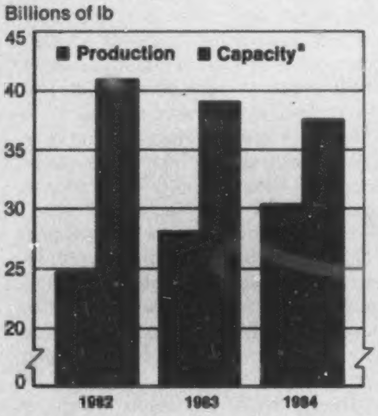
Key Chemicals

Ethylene

$CH_2{=}CH_2$

- ***Demand stronger***
- ***Capacity falling***
- ***Prices higher***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Thermal (steam) and catalytic cracking of hydrocarbons ranging from natural-gas-derived ethane to oil-derived gas oil (fuel oil)

MAJOR DERIVATIVES (U.S.)

Polyethylene 45%, ethylene oxide 15%, vinyl chloride 15%

MAJOR END USES (U.S.)

Fabricated plastics 65%, antifreeze 10%, fibers 5%, solvents 5%

FOREIGN TRADE

Negligible

PRICES

List prices between 26 and 27 cents per lb; continued discounting

COMMERCIAL VALUE

$6 billion for production, 1983

The kingpin of U.S. organics is about midway through recovery, with production moving up at more than double the long-term growth rate. Ethylene won't barrel along like this forever, but above-average growth looks guaranteed through 1984. Combined with a sharp cut in capacity, this gain is rapidly pushing up plant operating rates and restoring long-lost financial health.

The upshot is that ethylene's four-year nightmare since 1979 is finally over. At its worst in 1982, this savage interlude plunged production to little more than half of capacity and prices to discounts of 40%. Up to a quarter of capacity was shut down, some for keeps. Profits disappeared.

However, this dark chapter yielded faster than forecast to the present hopeful scene, and ethylene has a good shot at a new production record next year. For 1983, production probably will top 28 billion lb, up 14% from the very poor 24.7 billion lb in 1982. In turn, 1982 production was off 16% from 1981, the last year of fairly high operating rates. The production record remains 29.9 billion lb in 1979. Present forecasts for next year's production cluster around 30 billion to 31 billion lb, up another 10% or so from 1983.

As might be expected during a long recession-racked period, the operating economics of ethylene production units were scrutinized after 1979. Some units didn't pass muster and were shut down, either permanently or for long periods of mothballing. How much of this shutdown capacity will run again is undecided, but could get clearer soon as demand improves.

As 1983 began, some 2 billion lb per year of nameplate capacity already had come off the former official total of 41 billion lb. More dropouts showed up this year, and there could even be a few in 1984. In addition, some capacity is still down that normally would be operating if demand were higher. Probably 3 billion to 4 billion lb of capacity is out now for extended maintenance or modification to improve overall efficiency, including feedstock use.

Most such sidelined units are likely to be operating in 1984. They either will replace units now running that need maintenance or simply add capacity as needed to meet demand. One example of a steam cracker that has been down for some time is Arco Chemical's big second unit at Channelview, Tex., which is due for startup soon. When that happens, the first unit at the site is scheduled to go down for maintenance.

On a total nameplate basis, with a rough prorating for units operating only part of the year, the average operating rate for 1983 is about 75%. Most units actually are running higher than this, but most also are taking at least a month's down time.

In 1984, most of these units will run most of the year with only a few sidelined for major modification. One reason is that production next year could exceed demand, due to inventory building. This contrasts with 1983, when producers continued to trim inventories in the first half. In fact, ethylene demand in 1983 could be 1 billion lb greater than production because of this inventory liquidation. Inventories are now considered rock bottom.

An inventory push next year will help boost capacity use to more than 80% of the nameplate total. This level will be a dramatic improvement from the depths of 1982, when plant use sank below 60% part of the year. Since maximum output from ethylene plants in a year like 1979 was a bit more than 90% of capacity, producers may be able to fill another year or two of demand growth after 1984 with current capacity but only if all of it comes back on stream.

Most major products made from ethylene are doing well now. In one case, vinyl chloride output seems to have leveled off after an impressive spurt in the second quarter. Polyethylene, which accounts for nearly half of ethylene use, continues in strong demand. Ethylene oxide has lagged in the recovery because downstream antifreeze and polyester fiber producers took some time to reduce inventories, but both of these outlets are expected to provide good demand for ethylene in 1984.

These and other catch-up situations will propel ethylene through another year of unusually strong growth, industry analysts predict. By the end of 1984, the demand pipelines for derivatives again will be filled, and ethylene growth will throttle back to longer-term rates, now forecast at 4 to 5% per year through the 1980s.

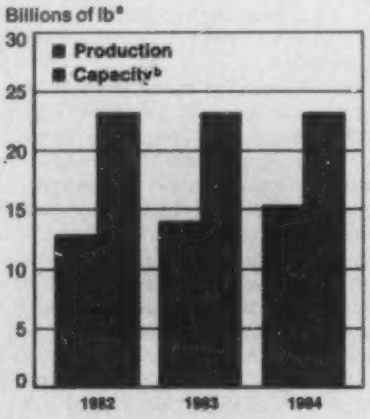
Key Chemicals

$CH_2{=}CH{-}CH_3$

Propylene

- ***Demand back up***
- ***Capacity flat***
- ***Prices up a bit***

PRODUCTION/CAPACITY



a Chemical and polymer grades. b First quarter.

HOW MADE

Recovered from cracked gas streams made in steam-cracking olefins plants and oil refineries

MAJOR DERIVATIVES (U.S.)

Polypropylene 25%, acrylonitrile 20%, cumene 10%

MAJOR END USES (U.S.)

Fabricated plastics 50%, fibers 15%

FOREIGN TRADE

Exports—negligible, imports—holding at about 500 million lb in 1983

PRICES

Chemical grade 19.5 to 21.0 cents per lb, polymer grade 21.0 to 23.0; continued discounting

COMMERCIAL VALUE

$3 billion for production, 1983

Propylene's recovery is slightly slower than ethylene's, but doesn't have as far to go. Propylene will get close to its old U.S. production high this year and easily set a new record in 1984. In fact, because of certain supply oddities, the propylene market could get a bit snug next year, and new capacity is nowhere in sight. Upward price pressure is a good bet.

Propylene's usable spare capacity is less than ethylene's, even though official capacity use is lower, because of propylene's peculiar nature as a coproduct wherever it is produced. Propylene supply is determined not so much by propylene demand but by demand for ethylene and gasoline, the primary products of the olefin plants and refineries producing propylene.

Propylene supply is also strongly affected by the great variety of feedstocks for ethylene. When ethylene and gasoline markets are weak as in the past recession and when ethylene feedstocks favor light liquids from natural gas as in the past several years, much less propylene is available than total capacity indicates. A lot of propylene capacity is, in fact, shut down.

Earlier in 1983, shifts in feedstock costs for steam-cracking olefins plants led to use of the maximum amount of light hydrocarbons, pushing propylene coproduct output very low. At the same time, oil companies anticipated flat gasoline demand, so refineries producing propylene operated at very low levels. All told, propylene output actually ran below demand, especially when chemical and polymer uses of propylene began pulling out of the recession.

Two things happened. Propylene inventories were drawn down to minimum levels by the end of the second quarter. And propylene users substituted some refinery-grade propylene for chemical-grade propylene in making derivatives that could stand the switch.

So where does that leave full-year 1983 estimates for propylene supply and demand? More murky than ever, say analysts of this elusive petrochemical. They say that production estimates based on official data from the U.S. International Trade Commission are low because not all propylene used in chemicals is being reported.

Industry estimates of propylene production for chemical and polymer grades run around 14 billion lb for 1983. Guesses on additional propylene used for chemicals add another half a billion pounds and perhaps more.

Plant capacity for propylene in various grades is essentially unchanged from last year, at about 23 billion lb per year. Some of this capacity can't run because some steam crackers are still shut down and some refinery units cracking heavier hydrocarbons are also down. Little change in capacity seems likely soon, in part because of this overhang of shut-down capacity.

Refiners are beginning to run propylene units harder because they want additional income and profit from propylene as the gasoline market slows. Prices are moving up for several propylene derivatives, notably polypropylene, the largest nonfuel use. Higher derivative prices allow propylene producers to get higher prices too for their product. Both list and actual selling prices have increased.

These price increases generally haven't slowed the demand gains for propylene. Another 10% production gain in 1984 seems likely especially if producers start building inventories. This gain will bring the total chemical and polymer grades production to at least 15.4 billion lb. It might mean futher increases in selling prices, too.

Such production next year would push average plant operating rates close to the late-1970s' highs, which never went much over 70%. Ordinarily, these use levels might suggest time had come for expansion. But most propylene producers will feel added investment really isn't needed and will continue to make good returns from existing investment all through 1984.

For propylene customers, a favorable situation for producers will mean a careful watch on supplies. It is not out of the question that propylene could get tight in the next year or two, with a sizable jump in price. At the moment, propylene prices are back down to their 20 to 30% level below ethylene prices. But propylene users remember what happened in 1982, when a crimp on coproduct propylene production forced propylene prices into an unprecedented premium over ethylene. This hurt performance in many derivatives.

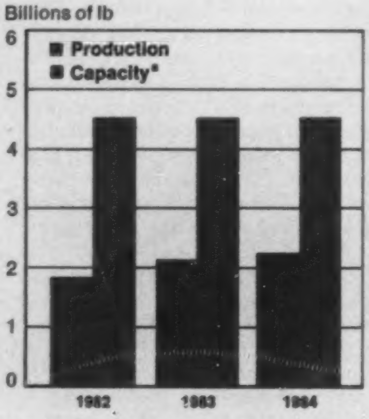
Key Chemicals

Butadiene

$CH_2{=}CH{-}CH{=}CH_2$

- ***Production low***
- ***Capacity flat***
- ***Prices off a bit***

PRODUCTION/CAPACITY



a First quarter; includes all extraction capacity.

HOW MADE

Recovered from steam-cracker product streams; dehydrogenation of butylenes made in oil refineries

MAJOR DERIVATIVES (U.S.)

Styrene-butadiene rubber 40%, polybutadiene rubber 20%

MAJOR END USES (U.S.)

Rubber products 70%, fibers 10%

FOREIGN TRADE

Exports—holding at about 70 million lb in 1983, imports—rising to more than 900 million lb

PRICES

List price 34 cents per lb; discounts general

COMMERCIAL VALUE

$650 million for production, 1983

As usual, butadiene is the maverick of the petrochemical business. It isn't recovering well and may have some bad news in store, the main culprit being imports. With no relief in its dominant rubber market, butadiene may start to lose plant capacity, much of which is shut down anyway. Altogether, butadiene is a case in which coproduct status and single-market dependence add up to a no-win situation.

About 70% of U.S. butadiene use is in rubber products, and more than 40%—production plus sizable imports—goes into styrene-butadiene rubber. Most of this rubber goes to transportation uses—tires and other fabricated rubber products in cars and trucks. So as transportation goes, so goes butadiene demand.

Large cuts in auto production in 1982 and moderate recovery in 1983 tell the tale for butadiene, too. Butadiene output fell 40% last year to 1.8 billion lb and will recover only 17% this year to about 2.1 billion lb. Plant capacity of 4.5 billion lb per year is running at a lowly 47%.

Why butadiene producers are caught with more than twice the plant capacity they really need becomes clear with a few seconds' glance at butadiene history. U.S. production actually peaked back in 1974 at 3.7 billion lb. Since then, output fell sharply in the 1975 recession, recovered most of the way by 1979, and then collapsed to half the old peak by 1982. Butadiene could get none of the new growth in the past decade in other U.S. organics because of the growing plight of the U.S. auto industry and the bulging forced butadiene surplus in Europe.

Aggravating the situation are certain current trends in the transportation industry. For example, changes in tire design are eroding demand for rubber, especially styrene-butadiene rubber. And almost all new cars produced in the 1983 model year are equipped with radial tires, which get much improved tread life. These two factors combined to reduce styrene-butadiene rubber production slightly in the first half of 1983 from first-half 1982. They also kept down possible gains in production of polybutadiene, an important part of tread rubbers.

Tires also are lasting longer simply because they aren't used as much as in the past. Last year continued the recent trend of fewer miles driven per car. This further reduces demand for tires in the replacement market, in turn reducing rubber and butadiene demand.

If these market forces weren't bad enough, butadiene's foreign trade adds another big dent for U.S. production. In 1982, more than a quarter of butadiene consumed in the U.S. was imported, mostly from Europe. Such imports were up 75% over 1981. In 1983, imports may be up another 20%. The reason is that European operators of steam-cracking olefins plants, which still are fed largely naphtha, need a foreign outlet for their large excess of butadiene coproduct. The U.S. is their sink, and U.S. butadiene imports of more than 900 million lb in 1983 will fill nearly 30% of demand, which is estimated at 3.0 billion lb or a bit more.

Partly because of imports, U.S. butadiene inventories are swelling. As the third quarter ended, inventories may have reached nearly a month's supply, considered high by most industry analysts. So inventories are dampening production plans for the rest of 1983.

With production badly crimped, the ax finally may fall on butadiene capacity, the independent part of which frequently has languished on standby in recent years. At this time, all stand-alone dehydrogenation units are believed shut down. (At some of these plants, the extraction sections may be running on C_4 hydrocarbons streams brought in from outside sources, including foreign plants.) Restarting these shut-down units is questionable for most. Even so, actual scrappage may take some time, since these units are easy to start up and run and represent little capital investment.

In the event that markets for coproduct butadiene and propylene tighten up and prices jump, steam crackers could be fed heavier hydrocarbons so that coproduct yield would increase. But industry analysts say that this won't happen for the rest of 1983 and at least the first quarter of 1984.

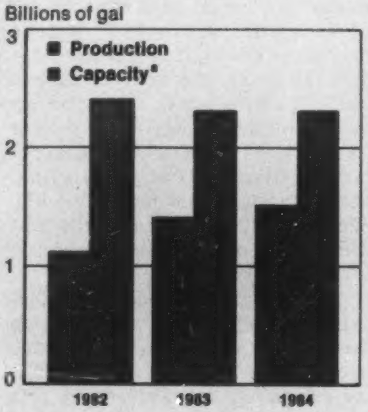
The net influence of these supply and demand factors will be a near standstill for U.S. butadiene production, analysts estimate. Imports will take care of any increase in demand, and inventories will remain large. Butadiene will be a buyer's market, and it will be priced to move.

Key Chemicals

Benzene

- ***Demand well up***
- ***Capacity flat***
- ***Prices up***

PRODUCTION/CAPACITY



[a] First quarter; includes all sources.

HOW MADE

Separated from aromatics streams from refineries, olefins plants, coke ovens; dealkylation of toluene

MAJOR DERIVATIVES (U.S.)

Ethylbenzene 50%, cumene 20%, cyclohexane 15%, aniline 5%

MAJOR END USES (U.S.)

Styrenic plastics 35%, phenolic polymers 20%, nylon 15%

FOREIGN TRADE

Exports—small, imports—down a bit to about 100 million gal in 1983

PRICES

List price up to $1.55 per gal

COMMERCIAL VALUE

$2 billion for production, 1983

Like its olefin cousins, benzene has enjoyed a sharp rebound this year, but its recovery isn't nearly as far along as is ethylene's. There is simply too much ground to regain: U.S. benzene output fell 36% from 1979 to its low point in 1982. So even an 18% pickup this year will leave benzene well short of full recovery, well shy of full capacity use, and only slightly firmer in its pricing.

Further, industry people close to benzene say that its recovery pace has slackened in recent months. At the moment, these sources are cautious about 1984, predicting a gradual flattening in year-to-year comparisons of benzene production. A differential has begun to show up in the performance of benzene's major derivatives. Some—for example styrene, made via ethylbenzene—are still doing well, but others such as phenol are posting just small gains in demand for benzene compared to a few months ago.

All told, benzene production in 1983 will exceed 1.3 billion gal and possibly 1.4 billion gal by some optimists' forecasts. That's up from less than 1.1 billion in 1982. However, for 1984, analysts expect only about half the 1983 production gain for a total of 1.5 billion gal. Some forecasts are not this high and indicate a production gain of only 50 million to 100 million gal, barring some fresh thrust in the general U.S. economy.

At the 1983 and predicted 1984 production levels, benzene's capacity use will remain fairly low, not much above 60%. This will leave plenty of room for new production growth, even though benzene, like propylene, cannot in practice run much more than 75% of nameplate capacity even in the best of years. For example, in a very tight market in 1979, benzene capacity use hit a high point of about 77%.

An added drag on capacity use comes from benzene's and its derivatives' foreign trade. Benzene itself has a significant trade deficit after little influence from trade in the late 1970s. Even with a 10 to 20% decline in 1983, benzene imports will be about 100 million gal. Benzene's exports are tiny, below 10 million gal.

Benzene derivatives add little cheer to the export picture. Styrene still may have large exports this year, but a decline is generally expected after that. Big drops already have come for other derivatives, including cyclohexane, nylon, and phenol.

Despite these market holes, capacity to make benzene remains about constant at 2.3 billion gal per year. The vast majority of benzene supply will come as usual from petroleum sources. And, as usual, reformate-derived benzene from petroleum refining will account for about half the supply for chemical uses. Pyrolysis gasoline from steam-cracking olefins plants will account for another quarter of supply, and dealkylation of toluene in independent plants will provide much of the remainder. Coke ovens will account for 5 to 7% of production, up from 1982 but still a small part of the total.

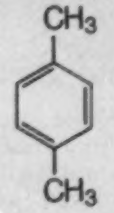
Only minor changes are due in benzene capacity. These will reflect changes mainly in operating conditions at the steam crackers. For example, there are seasonal fluctuations in benzene production from the crackers as operators shift slightly to lighter hydrocarbon feedstocks during the winter months and to heavier feedstocks in summer. The heavier feedstocks, which yield more benzene, are more economical for chemical use in the summer when their competing outlet in fuel oil is low.

In the non-steam cracker capacity for benzene, refinery sources are not expected to change very much. The independent hydrodealkylation plants may not run very hard, unless cost of feedstock toluene becomes quite attractive, but plant owners are unlikely to scrap these units either. Coke oven operators producing by-product benzene may have a lot of capacity that will never run again, considering the distress conditions in the ovens' main outlet, steel.

For consumers, of course, large U.S. overcapacity in benzene is a good deal. Consumers will continue to see quick deliveries and strong price competition this year and next. This month, list prices for benzene generally increased to $1.55 a gal, up a nickel. Competition will keep spot prices a bit below list after this increase, at least for a while, with variations depending on the level of petroleum refining operations and gasoline demand. Big upward price pressure isn't likely in 1984.

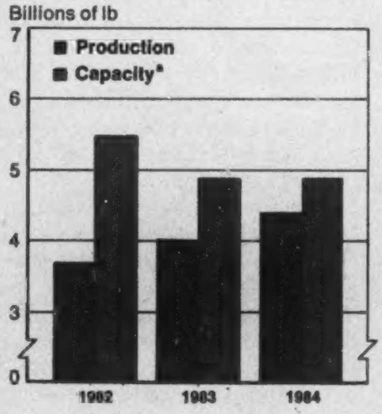
Key Chemicals

p-Xylene



- ***Demand swelling***
- ***Capacity use tightening***
- ***Prices pointing up***

PRODUCTION/CAPACITY



a First quarter.

HOW MADE

Separated from mixed xylene streams made in oil refineries and steam-cracking olefins plants

MAJOR DERIVATIVES (U.S.)

Dimethyl terephthalate 55%, terephthalic acid 45%

MAJOR END USES (U.S.)

Polyester fibers, film, and fabricated items (mostly bottles) almost 100%

FOREIGN TRADE

Exports—down to about 600 million lb in 1983, imports—small

PRICES

List price 26.5 cents per lb; discounts lessening

COMMERCIAL VALUE

$1 billion for production, 1983

p-Xylene has staged a dramatic turnaround in 1983 and could go into tight supply in 1984. That's quite a change from its bedraggled condition in 1982, when production slumped 37% from the old high of 4.7 billion lb in 1979. Back-to-back production rebounds of 10% in 1983 and 1984 will combine with a nearly 15% drop in plant capacity to catapault capacity use from 67% in 1982 to an expected 90% or higher.

Besides showing the value of an occasional capacity shakeout, which has proved very healthy for survivors, *p*-xylene is benefiting for once from its single-market dependence on polyesters. After falling 24% in the 1982 recession, polyester fiber demand is up nearly 10% so far in the Textile Economics Bureau's tabulations for 1983. The smaller market for *p*-xylene in polyester bottles, which rose even in the recession, is gaining strongly again this year and could be one of the fastest growing commodity chemical markets of the 1980s.

For *p*-xylene, such market health is causing a production leap from 3.7 billion lb in 1982 to more than 4.0 billion lb in 1983 and at least 4.4 billion lb in 1984. If the rosiest forecasts are right with production of 4.5 billion lb next year, *p*-xylene's capacity use would hit 92% of the first-quarter nameplate total of 4.9 billion lb per year. That's a flat-out rate. The squeeze would be on for customers, and producers might resort to cutting *p*-xylene exports to fill U.S. demand.

Customers will get some relief next year from added *p*-xylene capacity. Exxon Chemical will add some 150 million lb a year in an expansion and modernization project now under way at Baytown, Tex. If completed in early 1984 as scheduled and started up with minimum difficulties, this project could add possibly 100 million lb to 1984 *p*-xylene production. In another expansion, Chevron Chemical plans an additional 70 million lb of capacity at Pascagoula, Miss., to start up in late 1984.

Beyond these specific projects, some debottlenecking may be possible at other producers, especially those with relatively new plants. Industry sources suggest that demand pressures could add 5% to capacity this way without long shutdowns. One caveat for customers is that, if demand for *p*-xylene is very high, producers will have an incentive to run units longer than normal before maintenance shutdowns, making shutdowns longer than usual when they finally occur.

On balance, analysts guess that *p*-xylene might just squeak through 1984 with supply successfully pushed up to meet demand. One further aid may be completion of *p*-xylene plant projects abroad, which would take some of the pressure off U.S. *p*-xylene exports. Exports have run 20% of U.S. production in the past but may now ease down to 15% or less.

Markets for *p*-xylene will be up on all sides in 1984, analysts forecast. For example, polyester for fibers is due for a significant pickup in exports to China, which stopped importing U.S. product in 1982 and 1983 while negotiating a new textile trade agreement with the U.S. The pact is now in hand, and the Chinese are expected to take a large volume of U.S. polyester in 1984. These exports may offset a somewhat reduced recovery rate expected for polyester fiber in the U.S. next year.

The U.S. polyester beverage bottle business will continue its handsome growth in 1984 as one of the few new large-volume commodity chemical markets of recent years. One slight brake on this new growth is that, to cut costs of the finished bottles, fabricators are testing multilayer bottles made with polyethylene and a polyester barrier layer. However, analysts believe such new hybrid plastic bottles probably won't affect *p*-xylene demand very much in 1984.

In sum, *p*-xylene may be the first basic U.S. petrochemical to fully extricate itself from the prevailing gloom of the early 1980s and become a robust business as in brighter chemical decades of the past. A large part of *p*-xylene's secret is good long-term growth, which has made the chemical's strong tie to polyester an asset, even if a risky one in recessions. With by far the strongest volume growth in the past decade among the five major basic petrochemicals, *p*-xylene will have output in 1984 double that of the early 1970s. Only propylene is within hailing distance. And *p*-xylene likely will reach new production highs in 1985.

Turnaround ahead for antioxidants use

U.S. consumption of antioxidants to stabilize plastic resins will grow 4.7% per year to 44 million lb in 1986, worth $147 million, from 35 million lb in 1981, valued at $88 million. This is the estimate of Roger Lacallade, market manager for specialty chemicals at Uniroyal Chemical, Naugatuck, Conn. He chose 1981 as a base year because the recent recession depressed sales to an abnormally low 32 million lb, which sold for $78 million.

Recovery of such polyolefin markets as automotive and housing likely will bring upturns in the antioxidants compounded into them by resin producers. "But it could be stifled or stopped flat," Lacallade warns, "by the huge federal deficit and fiscal and monetary policies." Assuming a mild economic recovery, however, he goes on to make predictions about antioxidants sales performances.

Lacallade notes that in polyolefins, a key market for antioxidants, imports are growing fast. This has a negative impact on U.S. antioxidant consumption. "But we see growth in domestic linear low-density polyethylene production as being able to offset this at least a little." Too, a rapid rise in the market share of polyvinyl chloride (PVC) for pipe has cut into antioxidant sales for acrylonitrile-butadiene-styrene (ABS) resin in this use. But on a more positive note, Lacallade adds, "In any case, we don't see foreign competition being as severe a threat to styrenics as to polyolefins."

A pattern of antioxidant use in various resins has been developed by the research and consulting firm SRI International, Menlo Park, Calif. Polypropylene takes 33% of all antioxidants and requires higher loadings than many other polyolefins. This is because the highly branched structure of this polymer contains many tertiary carbon atoms, which are prime sites for radical and peroxide formation. ABS also needs large amounts owing to the carbon-carbon double bonds present. About 19% of antioxidants are used in ABS, according to SRI. PVC accounts for 16%, such other polyolefins as polyethylene for 15%, high-impact polystyrene for 12%, and other resins for 5%.

The biggest single class of antioxidants for plastic resins is hindered phenols, including butylated hydroxytoluene (BHT). This class comprised 57% of the pounds and 75% of the dollars of U.S. antioxidant sales in 1981, a relative position that will be maintained through 1986. Lacallade estimates that high-molecular weight diphenols and polyphenols will grow at 5.7% per year in the period, but use of BHT itself will increase only 2% annually. This is because low-molecular-weight BHT is limited to resins that process at 300 to 400 °F. Too, there have been shortages in raw material *p*-cresol and decreases in BHT capacity. Principal U.S. producers of BHT for this industry are Koppers, Sherwin-Williams, and Uniroyal Chemical, which have 80% of the market, according to Lacallade. For other hindered phenols, he estimates that Ciba-Geigy sells 50% of the total, and Ethyl and B. F. Goodrich together account for another 20%.

These hindered phenols are primary antioxidants, which means that they work by quenching free radicals. Radicals trigger polymer degradation. Such secondary antioxidants as thioesters and organophosphites destroy peroxides, which might otherwise form radicals. Lacallade estimates that use of thioesters like distearyl β,β'-thiodipropionate will grow only 2.5% per year through 1986, whereas organophosphites like tris(nonylphenyl) phosphite will forge ahead at 7.4% yearly. This is because thioesters are antagonistic toward the hindered amine ultraviolet light absorber additives now becoming so popular. Thus many resin producers will reformulate around organophosphites. American Cyanamid and Evans Chemetics, a subsidiary of W. R. Grace, have 75% of the U.S. market for thioesters for plastic resins, Lacallade says, and Borg-Warner and Uniroyal Chemical sell 75% of the organophosphites.

Antioxidant market will be 44 million lb in 1986 . . .

Millions of lb	1981	1982	1986
BHT[a]	7.7	6.8	8.5
Hindered phenols[b]	12.3	11.4	16.2
Phosphites	7.0	6.4	10.0
Thioesters	6.0	5.3	6.8
Other	2.0	1.8	2.5
TOTAL	35.0	31.7	44.0

. . . and will be worth about $147 million

$ millions	1981	1982	1986
BHT[a]	$12.8	$10.2	$ 15.9
Hindered phenols[b]	52.9	47.9	93.2
Phosphites	8.1	7.4	15.7
Thioesters	10.2	8.9	15.3
Other	4.0	3.4	6.7
TOTAL	$88.0	$77.8	$146.8

[a] Butylated hydroxytoluene. [b] Other than BHT.
Source: Uniroyal Chemical

For their own part, Uniroyal Chemical managers pin their hopes on a recently introduced hindered phenol that doubles as a metal deactivator. Metal deactivators chelate metals like iron and copper, which are capable of more than one oxidation state, and which thus might catalyze resin autooxidation. Sources of such metals are pigments, fillers, and polymerization catalyst residues.

The Uniroyal compound is *N,N'*-oxamidodiethyl 3-(3,5-di-*tert*-butyl-4-hydroxyphenyl) propanoate. The company also has just introduced a synergistic blend of that compound with tris(2,4-di-*tert*-butylphenyl) phosphite, which is a solid organophosphite. These products are part of Uniroyal Chemical's overall effort to develop more high-performance hindered phenols and organophosphites, while remaining strong in such work-horse products as BHT and tris(nonylphenyl) phosphate. Both products have gotten Food & Drug Adminmistration approval. Uniroyal Chemical marketing specialist Gerald J. Hollmann says that these approvals open up the entire potential 12 million lb-per-year market in non-BHT-hindered phenols to these products. This is because plastic processors will have assurance of the overall safety of these additives even when used in other than food and drug applications. □

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third quarter, barring companies that went from deficits to profits, was at Reichhold Chemicals. Reichhold's earnings from continuing operations increased 400% from third-quarter 1982 to $5.5 million. However, the earnings gain weighing most in the industry totals was from Dow Chemical, whose profits rose 146% to $86.0 million. Without Dow, the overall increase would have been just 27.5%, almost 10 percentage points lower.

Dow's president and chief executive officer, Paul F. Oreffice, says, "We have come a long way from the dismal economic conditions that the chemical industry faced only a year ago. Even though the nine-month earnings are lagging 1982, our core businesses are in far better shape versus third-quarter 1982 and we expect continued improvement." Earnings from operations at Dow, excluding extraordinary items, are 12% ahead of 1982 through the first three quarters.

Another company happy with the chemical economy is Celanese, whose chairman, president, and chief executive officer, John D. Macomber, says, "The U.S. economic expansion is continuing, and domestic demand has picked up for our chemicals, fibers, and specialty products in the automotive, housing, and other industries. We achieved a profit this quarter for the first time in a year."

A "we are pleased" comment also comes from Du Pont chairman Edward G. Jefferson, who at C&EN press time disclosed a 60% earnings jump for the company in the third quarter from 1982. Du Pont's chemical earnings more than doubled on an 11% physical volume increase. Its chemical plants ran at 72% of capacity, up from 67% in third-quarter 1982 and 62% in early 1983.

All told, the economic improvement bodes well for the chemical industry this year. Although total profits are still not fully recovered, another big gain in the fourth quarter should do the trick. Such a gain is in the bag, since the comparison will be with the worst recession quarter of 1982. And unless the general U.S. economy falls apart, a banner year is in store for the chemical industry in 1984. □

Senate kills Clinch River breeder reactor

The rollercoaster career of the Clinch River breeder reactor project is finally over. The Senate, which has been keeping the project alive for years, voted last week to delete the $1.5 billion earmarked for the project from the fiscal 1984 supplemental appropriations bill. The House, where opposition to the project is intense, didn't even bother to consider funding it this year.

The reactor, to be sited on the Clinch River in southeastern Tennessee, was aimed at demonstrating the liquid-metal fast breeder reactor, which would produce more plutonium fuel than it used while generating electricity. The electricity was to be supplied to the Tennessee Valley Authority.

The project has been plagued by cost overruns for years and there have been recent assertions that its technology is by now outdated. When the demonstration reactor was first authorized in 1971, the cost was put at $400 million, with more than half to be supplied by electric utility companies. The most recent cost estimate is $4.5 billion, with utilities expected to provide $1 billion, which they have seemed reluctant to do.

The Department of Energy seems to have bowed to the inevitable, saying that it is disappointed with the vote but will begin an orderly termination of the project on which $1.7 billion already has been spent for design and engineering work, excavation, and some major components. DOE estimates that closing the project down will cost $150 million to $350 million. □

Quality of science students may have improved

The quality of science and engineering students—both undergraduate and graduate—seems not to have changed much over the past five years, and there is some indication the quality may have improved. That's the overall impression from a survey of senior academic officials conducted for the National Science Foundation by the American Council on Education.

Judgments of quality were obtained from a sample of 486 institutions with four-year undergraduate programs and 383 with graduate programs. No attempt was made to distinguish between science and engineering students or between students in various science or engineering fields.

Specifically, 60% of those officials queried reported "no change" in quality of undergraduate or graduate students. Most of the rest, however, expressed views indicating improvement, with 25% saying "significant improvement" among science and engineering undergraduates and 15% saying "significant decline." For graduate students, 28% of the graduate deans surveyed saw an improvement in quality and only 12% reported declines.

The survey asked for subjective judgments, but it did ask also for the officials to provide the bases for

Graduate deans rate five-year change in applicant quality

Type of institution	No significant change	Significant improvement: Overall	Significant improvement: In a few fields	Significant decline: Overall	Significant decline: In a few fields
All institutions	60%	10%	18%	6%	6%
Doctorate granting	59	11	16	5	9
Nondoctorate granting	61	9	20	7	2
Publicly controlled	58	13	17	6	6
Privately controlled	63	5	21	5	6
50 largest science/engineering doctorate	61	6	21	4	9

Note: Opinions of graduate deans about change in quality of applicants for graduate study in science/engineering fields over the five years to 1982. Sources: National Science Foundation, American Council on Education their conclusions. These answers show that many different bases were used, especially among the groups that formed different judgments.

For example, at the undergraduate level, the principal indicators cited as the basis for opinions were faculty impressions, 32%; trends in achievement test scores, 29%; high school grades or class rank, 21%; requirements for remedial courses in mathematics, 12%; and other factors, 6%. Different indicators tended to be used by those reporting no change, improvement, or decline.

At the graduate level, there was a similar pattern, with graduate deans basing their opinions on faculty perceptions, 29%; undergraduate grade-point averages, 28%; trends in applications from graduates of high-quality undergraduate institutions and Graduate Record Examination scores, 20% each; and other factors, 3%. ☐

U.K. considers sites for nuclear waste disposal

Radioactive waste may end up in an unused anhydrite mine belonging to the U.K.'s Imperial Chemical Industries. The site, beneath ICI's major chemical complex at Billingham on England's northeast coast, is one of two being considered. The other is a thick clay deposit in Bedfordshire north of London.

The locations have been selected by the U.K.'s Nuclear Industry Radioactive Executive. NIREX was set up last year by British Nuclear Fuels Ltd., the U.K. Atomic Energy Authority, and the country's electricity generating boards to coordinate plans for the management and disposal of low- and intermediate-level radioactive wastes resulting from the U.K.'s nuclear activities.

The next step will entail thorough field studies of the sites' potential suitability for construction of radioactive waste depositories. Paramount will be an evaluation of the geology of the areas. This will take several years to complete.

If the sites prove suitable, NIREX will seek planning permission to move ahead with the work. The hope is that the Bedfordshire repository could be ready to receive waste by the end of the decade. It could accommodate some 353,000 cu ft a year of short-life, medium-level material incorporated in concrete or resin, and packaged in steel or concrete drums. These would be buried in a series of trenches and covered with the thick clay. The Billingham mine, about 750 feet below ground level, has a potential capacity of 388 million cu ft. It would be the repository of long-life, medium-level waste.

Not surprisingly, people who live and work in the vicinity of the two areas are greatly concerned at the prospect of radioactive material being dumped there. Paul Marsden, deputy chairman of ICI's agricultural division, "regrets" the selection of Billingham. "We would like to be left alone to do the things we are good at: making chemicals," he says. ☐

Toxicity lab officials found guilty of fraud

A U.S. district court jury in Chicago has found three former officials of Industrial Bio-Test Laboratories guilty of multiple counts of fraud, stemming from falsification of data obtained in four animal toxicity tests conducted by the firm (C&EN, June 29, 1981, page 5). Meanwhile, officials of the National Toxicology Program have expressed doubts about the validity of toxicity tests conducted by other laboratories.

In a joint trial, after seven months of complex testimony and 11 days of jury deliberation, Moreno L. Keplinger, former manager of toxicology at Bio-Test, was found guilty of six of eight counts charging alleged mail or wire fraud, or false statements made to government agencies. James L. Plank, a former assistant to Keplinger, was found guilty of five counts. Paul L. Wright, former section head for rat toxicology, was found guilty of three counts. Each of the counts carries a maximum sentence of five years in prison. No date for sentencing has been set; post-trial motions for acquittal will be argued next Feb. 17.

Joseph C. Calandra, former president of the Northbrook, Ill.-based firm, also had been indicted and brought to trial with the others. In his case, however, a mistrial was declared in July, to allow him to undergo heart surgery. Whether he will be retried has not yet been decided.

In the late 1960s and early 1970s, Bio-Test, then a subsidiary of Nalco Chemical, was a leader in the fast-growing field of toxicity testing. But a 1976 inspection by Food & Drug Administration officials revealed deficiencies in test procedures. Thereafter, things fell apart at Bio-Test. In 1977 the firm admitted to "material defects" in rodent studies. A number of previously approved drugs and pesticides had to be retested. Customers brought suits. Bio-Test sold most of its facilities, but a skeleton staff remains in Northbrook to tidy up loose ends.

The 1981 criminal indictment (and 1983 trial) dealt with tests of four compounds: naproxen, an antiarthritic drug; trichlorocarbanilide, an antibacterial; a herbicide; and a pesticide. Safety of all four products was reconfirmed after retests or audits.

In another development, officials of the National Toxicology Program say they plan to review 166 unpublished studies made by several laboratories. They also may audit some of another 250 studies, results of which already have been published.

The action was prompted, NTP says, by one allegedly flawed test of the carcinogenicity of methylene chloride, made by Gulf South Research Institute, a not-for-profit organization based in Baton Rouge, La. The findings in that case convinced program officials that they should review not only 25 other studies by Gulf South but all the other unpublished studies made for the program by other laboratories. NTP stresses that there is no suggestion of fraud in the Gulf South case, just "sloppy science."

Gulf South president James H. Clinton concedes that the lab has had some problems and has made some changes. But, he argues, the study, made from 1978 to 1980, is now being judged by stricter 1983 standards. ☐

Alternative Methods Could Cut Animal Use in Toxicity Tests

Scientists are encouraged by preliminary results from cell culture and other techniques to assess eye irritation and various types of toxic effects from chemicals

Ron Dagani
C&EN Washington

A dog with large, liquid eyes stares through the bars of his cage. Above this photograph the caption reads: "Would you pay someone to kill this animal?"

This advertisement and others like it that ran in several newspapers this year, attacks a test called the LD_{50}, which is used to determine the acute toxicity of chemicals in animals. The test "causes agonizing death for millions of lab animals," the ad states, "and you pay for it!"

Media campaigns like this one, designed and carried out by well-financed animal welfare groups, have galvanized the general public and the scientific and regulatory communities into a greater awareness of the widespread use—some would say misuse—of animals in research and testing of chemicals and consumer products.

With funding from animal rights groups, corporations, foundations, and others, scientists have intensified their efforts to find and validate alternative tests and research methods that do not subject animals to suffering—or better yet—do not use animals at all.

It is a tall order. Animals have played a crucial role in toxicology, biomedicine, and other fields of science for as long as bench chemists have depended on test tubes and beakers. About 70 million animals are used each year in the U.S. for toxicity testing and biomedical and behavioral research, according to the Office of Technology Assessment. The vast majority of these are mice and rats. But the rabbits, cats, dogs, monkeys, and other higher animals used number in the hundreds of thousands.

Some 20% of all these animals, about 14 million, are used in toxicity testing, an enormous enterprise aimed at protecting humans from the chemical web that is an inextricable part of modern life. Whether they are used to evaluate the potential eye irritancy of a new shampoo, or the possible carcinogenicity of an industrial chemical, laboratory animals are the unwilling stand-ins for humans.

Many believe that humans can be protected adequately without resorting to such extensive use of live animals. The alternatives include the use of tissue and cell cultures, isolated tissues and organs, simulated tissues and body fluids, and bacteria. These are known as in vitro methods. In addition, computers are playing an increasingly important role in helping scientists develop mathematical models and quantitative structure-activity relationships that can identify potential chemical troublemakers.

The current drive to reduce animal use or find replacements for animals in the lab, particularly in the testing of consumer products, is motivated by several factors. First and foremost is the animal welfare movement. Animal activists have questioned the morality of using other species to benefit humans. They also have deftly played to the hearts of the public, tying into many people's feeling of kinship to animals.

But the practical shortcomings of animal tests also have served as an impetus. Lab animals have become expensive, and the data they provide tend to be imprecise and sometimes of limited usefulness. Cell culture systems, for example, are simpler and cheaper than using animals. And in light of recent advances made in such in vitro methods, these alternatives hold out the promise of providing scientists with more precise quantitative data.

None of these potential alternatives, however, offers a panacea. "Many of the whole-animal tests now used to measure irritancy or systemic and neurotoxicity rely on the interaction of a multitude of organ functions and [chemical] products," explains Dennis M. Stark, head of the Laboratory Animal Research Center at New York's Rockefeller University. "This interaction is not going to be easily measured in isolated culture systems." Stark, along with many other researchers, believes that many alternative bioassays may be necessary, as a battery, to obtain the same information elicited from a whole-animal test.

During the past few years, the animal rights movement has pummeled the consumer products industry especially hard. It has taken aim at two specific tests—the Draize and LD_{50}. Besides stimulating research into a variety of alternatives, these efforts have succeeded in reducing the numbers of animals used in toxicity testing. Thus far, however, no proven, comprehensive replacements for these animal tests have emerged, but researchers are encouraged by their preliminary results.

The Draize test, named after the pharmacologist who standardized it in 1944, is widely used by manufacturers to determine the potential eye irritancy of a plethora of consumer, pharmaceutical, and industrial products. The test substance is placed in one eye of an albino rabbit; the other eye, untreated, serves as the control. An irritant will cause inflammation of the treated eye. The degree of inflammation is assessed visually by comparing the appearance of the eye to standardized photographs.

To the nonscientist, the idea of using "cute bunny rabbits" to test potentially eye-irritating, and hence painful and possibly blinding products, may seem downright diabolical. But the choice is dictated by scientific logic. The rabbit's eye, being thinner than a human's, also is more sensitive. Also, the animal's tear glands are not as effective as a human's in washing away irritants. And because an albino rabbit's eyes contain virtually no pigment, it's easier to see inflammation or damage when it occurs.

The procedure used for rating the degree of inflammation and damage caused by a substance in the Draize test is extremely subjective, however. Several studies published during the 1970s showed that the use of the test to pigeonhole substances as either mild, moderate, or severe irritants is subject to much variability. As one scientist tells C&EN, "Pink to you might be red to me."

These results served as ammunition for animal advocates like Henry Spira, who charged that the Draize test was used indiscriminately and that it was repeated too often with known irritants. Spira pulled together a coalition of more than 400 groups that, despite their individual agendas, were adamant in their opposition to the Draize test. Revlon, a major user of the test and a giant in the glamorous world of cosmetics, was attacked in full-page newspaper ads and beseiged by crowds of protesters marching past the front door of its New York City headquarters in 1980.

Although Revlon had already begun to look into possible alternatives to the rabbit eye-irritancy test, it made a grand gesture to calm the public waters: The firm announced a three-year, $750,000 grant to Rockefeller University to fund "an exploratory investigation" into the feasibility of developing a nonanimal alternative to the Draize test. Momentum picked up as other well-known firms, like Bristol-Myers and Avon Products, made large contributions to the alternative-test research kitty. A $1 million fund set up by the Cosmetic, Toiletry & Fragrance Association (CTFA) was used to create the Center for Alternatives to Animal Testing at Johns Hopkins University in Baltimore. Thus, university research to find alternative tests began in earnest.

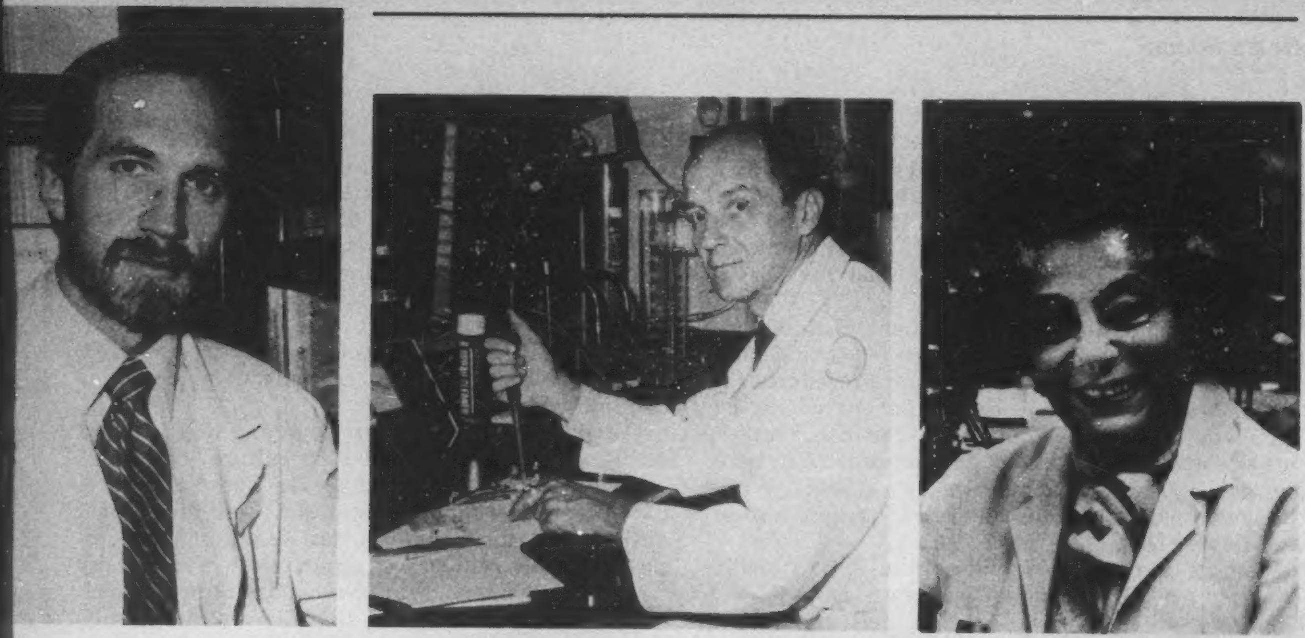
At Rockefeller's Laboratory Animal Research Center, Stark and colleagues Ellen Borenfreund, Charles Shopsis, and James Walberg are developing and testing a series of assays that could serve as a possible alternative to the Draize test.

A successful alternative, they explain, should satisfy several requirements. First, the test must be easy to standardize, so that data from different labs can be reproduced readily. Second, it must be able to detect toxicity over a wide range of different chemical structures and target tissues. Third, the alternative should be able to evaluate the toxicity of complex mixtures. And fourth, it should be able to indicate whether recovery from the toxic insult is possible.

The assays under development at Rockefeller take several different approaches, but in general, they try to mimic several elements of the inflammatory response of the rabbit's eye in vitro. The process of inflammation is still not completely understood, but many of the structural and chemical changes that accompany eye irritation have been identified.

Biochemist Borenfreund, for example, is examining several different cultured cell lines for characteristic markers of irritation. These markers, which include synthesis of tissue-specific proteins and changes in cell shape and cell clustering, provide much more sensitive and subtle signals of toxicity than the biological endpoints, such as cell death, that toxicologists traditionally have used. In Borenfreund's assays, the endpoint is not cell death, but the highest tolerated dose—the concentration of toxicant that produces only minimal cellular changes.

In a similar vein, Shopsis has developed a sensitive assay based on a biochemical marker—the uptake of uridine into cultured mouse fibroblast cells. Uridine is a nucleoside that cells use to make RNA. Cells in culture will absorb uridine from the medium at a



(Clockwise from top left) Rockefeller's Walberg, Stark, Borenfreund, and Shopsis are developing a battery of assays that could be used as a possible replacement for the rabbit eye-irritancy test

measurable rate. This rate is a sensitive indicator of the health of the cell and the functioning of its membrane. When an irritant is added to the cell culture, Shopsis explains, the chemical interferes with transport of uridine through the membrane. Using radiolabeled uridine, Shopsis can determine the concentration of the irritant that causes uridine uptake to be inhibited by 50%. This value is used to rank the test substances according to their potency as irritants.

Shopsis tested more than 40 different substances using this assay and has found that his ranking correlates beautifully with Draize test scores for the same chemicals. What's more, Borenfreund's results using different cell markers also correlate with Shopsis', strengthening the notion that many different markers could be used to determine a chemical's irritancy potential in vitro.

The Shopsis assay also can measure the cells' recovery from the toxic insult. If a nonlethal concentration of irritant is used, its removal from the culture medium eventually will allow full membrane function to resume, as evidenced by a normal rate of uridine uptake.

Stark's contribution to the Rockefeller battery of alternative assays is, he admits, "farthest back on the burner," but it is no less intriguing. His assay involves a different aspect of the in vivo inflammatory response—the migration of macrophages to injured tissue. Macrophages are large white blood cells that engulf foreign material and move in response to the presence of certain chemical agents. The agents that attract macrophages are induced wherever inflammation occurs. Thus, regardless of the chemical identity of an irritant, if it produces inflammation, macrophages will be attracted to the injured site.

Stark wants to determine whether this migratory response, as measured in vitro, is correlated with irritancy observed in the live animal. To do this, he is studying how cultured macrophages react to fluids from mouse cell cultures that have been exposed to various irritants. Fortunately, the identities of the macrophage-attracting compounds present in these fluids needn't be known for the assay to work, Stark notes. His hope is that the migratory response, quantitated using special equipment, will correlate with the Draize scores of the irritants.

Unlike the other members of the Rockefeller team, veterinary pathologist Walberg is working with live rabbits. He has developed an apparently painless modification of the Draize test that provides objective data. Walberg exposes the eye of a rabbit to a dilute solution of a test compound. He then rinses the eye with distilled water after one hour and at predetermined time intervals thereafter. The cells that are washed out of the eye are counted and examined under the microscope.

In a series of tests using various alcohols of known irritancy, Walberg found that the number of such exfoliated cells obtained at various time intervals after exposure to the alcohols paralleled, in general, the Draize test scores. The Draize scores were obtained by visually assessing inflammation in the treated eyes at the same times the eye rinses were done. In the case of one strong irritant, the cell count actually predicted acute, severe inflammation earlier than the Draize assessment.

Walberg's modification is not intended to replace the Draize test. Rather, he hopes it will "provide more objective data upon which validation procedures for alternative methods can be based." But animal activist Spira would like to see Walberg's test used as a substitute in corporate labs, at least until a validated in vitro alternative is available. Spira already has begun to put the pressure on companies to take a long, hard look at the Walberg test.

Walberg himself does not oppose Spira's tactic. Whether his cell exfoliation procedure is used as a Draize replacement or as a tool to help validate in vitro alternatives, its use, he says, is likely to reduce the need for repeated testing and decrease the number of animals used.

Researchers elsewhere are using different cell culture systems and a variety of methods to ascertain how well a chemical's irritancy potential can be predicted in vitro. For instance, at the University of Washington, Seattle, assistant professor of ophthalmology Kwan Y. Chan is focusing on rabbit corneal epithelial cells in culture. His assay involves measuring levels of plasminogen activator, an enzyme that is secreted in large amounts when cells in the cornea are injured or undergo drastic structural changes.

Chan's project, which is funded by the Johns Hopkins Center for Alternatives to Animal Testing, began only last May. Presently, he is trying to establish whether release of this enzyme can be used to signal cell damage caused by a chemical irritant such as bleach.

At about the time Chan was beginning his project, William H. J. Douglas and Stanley D. Spilman were finishing theirs at Tufts University School of Medicine in Boston. The Tufts researchers used cultured endothelial cells from calves' eyes. They first incubated the cells with sodium chromate labeled with radioactive chromium-51, which binds to the cells. Then the cells were exposed to a test substance and the amount of chromium-51 released by the cells was measured. Douglas and Spilman tested 56 substances in this way and ranked them by their potency to injure cells, as determined by the degree of radioisotope release. This in vitro ranking, they say, generally correlates with the substances' irritancy potentials as determined in vivo.

Douglas and Spilman were planning to go on and see how their assay worked on cultures of human corneal endothelial cells. However, both researchers left Tufts earlier this year, and as a result of personal difficulties on the part of Douglas, it's uncertain whether their study will be continued elsewhere. In any case, the New England Anti-Vivisection Society, which had funded the project, has disseminated their results to leading toxicologists around the U.S.

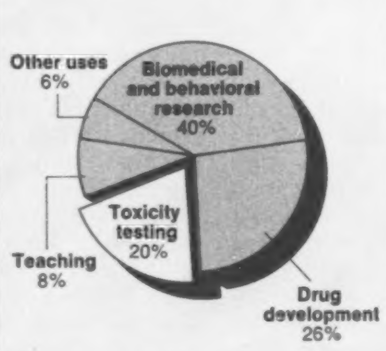
Although Douglas thinks the ideal in vitro replacement for the Draize test must rely on human corneal tissue, research suggests that corneal cells aren't essential to mimic eye inflammation or damage. Rockefeller's Borenfreund, for example, has studied the effects of about 40 chemicals, including alcohols, ketones, surfactants, and drugs, in five cell lines from different organs and species, including rabbit epithelial corneal cells. She found that the toxicity rankings of the compounds agreed very well in all the cell cultures, as well as with Draize scores.

But cell cultures are not the only in vitro methods that can be used to screen chemicals for irritancy. In fact, Joseph Leighton, an experimental pathologist at the Medical College of Pennsylvania, Philadelphia, takes a stronger view. He believes that tissue culture models are inadequate for simulating the inflammatory response in the body. Inflammation is expressed in a major way by changes that occur in blood vessels, he explains. In the Draize test, the inflammatory response involves the blood vessels in the rabbit's eye. But cell cultures lack blood vessels.

Rodents are most commonly used lab animals . . .

Animal	Number[a] (in thousands)
Mice	45,000
Rats	15,000
Birds	5,000
Frogs	3,000
Hamsters	1,000
Guinea pigs	1,000
Rabbits	750
Dogs	250
Ungulates	200
Cats	100
Primates (nonhuman)	25
TOTAL	71,000

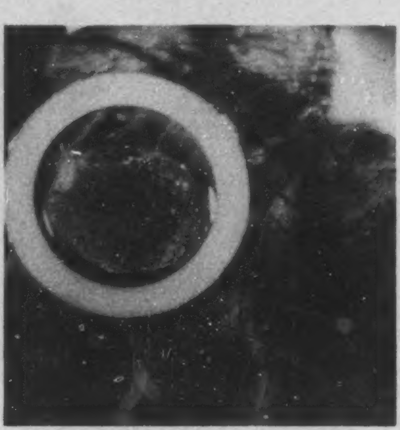
. . . and 20% of all lab animals end up in toxicity testing

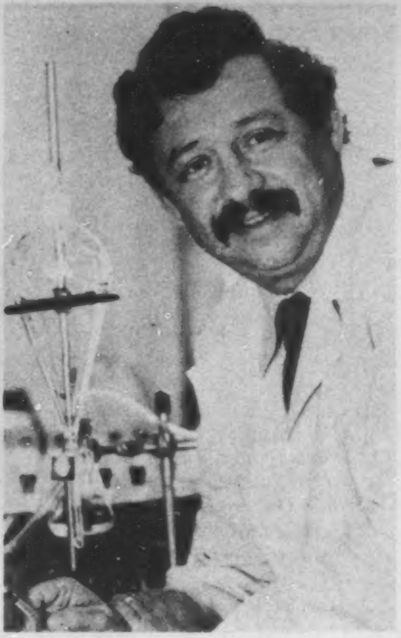


a Average number of laboratory animals used per year in research and testing in the U.S.
Source: Office of Technology Assessment

So Leighton chose to study irritancy in a tissue rich in blood vessels: the chorioallantoic membrane of chick embryos. This membrane forms under the shell during the incubation of the chick and serves as "a stand-in lung" for the embryo, he says.

With major support from the New York City-based American Fund for Alternatives to Animal Research, Leighton has been testing household products on the membrane. The membrane responds to chemical irritants like a living tissue—which it is—rather than like a cell culture. But because the membrane lacks nerves, the embryo feels no pain.





Chemical applied to chorioallantoic membrane causes severe reaction in circle (above) in work being done by Leighton (left). Goldberg's animal alternatives center at Johns Hopkins is funding similar research

So far, Leighton's bioassay can readily pick up severe irritants. But the test has difficulty in distinguishing between moderate and mild irritants in the Draize test. "We've a lot of work to do there," he says. His test could be useful in screening out severe irritants.

Recently, Colgate-Palmolive has shown interest in Leighton's work and has given him support. The firm plans to collaborate with him on a study that will check how reproducible his assay's results are, and how well they correlate with rabbit-eye data.

Although university research on Draize alternatives is highly visible, the industry that traditionally has depended on animal toxicity tests before marketing its products is making serious in-house efforts to find nonanimal test alternatives. These efforts are carried on largely behind the scenes because companies that make cosmetics, household products, and other consumer items usually consider their own self-developed test methods to be proprietary.

For example, Johnson & Johnson Baby Products has spent "a great deal of time and money" in the past six years to develop in vitro screening procedures to weed out harsh ingredients, according to irritancy researcher John J. McCormack. At a bioassay symposium held in 1981, McCormack presented details of an eye-irritancy test that he developed using mast cells from rat peritoneal tissue. That particular corporate disclosure, however, was exceptional. J&J rarely reveals such information, he explains, because it could erode the firm's "enormous advantage" in marketing mild products. The firm no longer uses the mast-cell test, he tells C&EN; it has been replaced by proprietary tests that presumably are superior.

Many other companies also screen out severely irritating products by in vitro methods, long before those products reach the animal testing stage. But in that penultimate stage, corporate testing labs have found that, for the time being, in vivo tests are unavoidable to ensure their products are safe for human use.

Even so, the trend is toward using as few animals as possible and minimizing their stress. At Procter & Gamble, for instance, scientists are using a refinement of the Draize test that calls for one tenth the amount of test substance normally used. Revlon also tests products in the rabbit eye in reduced quantities. Moreover, Revlon technicians sometimes rinse the rabbit's eye almost immediately after a test material has been applied. Some labs, like Avon Products', also administer local anesthetics to rabbits to reduce their discomfort. Most firms have eliminated repetitive tests. Avon has cut animal use by testing only final formulas, not interim ones. And Revlon has reduced the number of rabbits used more than 30%.

Besides these efforts, the cosmetic industry as a whole is funding outside studies that are delving into the basic mechanisms of inflammation and other toxicological responses. Much of this research is being sponsored by the Johns Hopkins Center for Alternatives to Animal Testing. The center, which materialized in 1981, already has assigned 16 grants to independent research groups: 14 in the U.S. and two in England. Of the U.S. projects, eight are clustered at Johns Hopkins.

Director Alan M. Goldberg, a neurotoxicologist, says that these research programs, which ultimately are aimed at developing alternatives to the Draize and other tests, are geared to exploring "areas of toxicity that are generally not being looked at by other groups."

The projects, Goldberg notes, are "highly focused" in three areas: responses of specific cell systems, structure and function of membranes, and secretory responses of cells and organs. The results coming out of these studies, he says, will provide the fundamental information necessary to develop a new generation of animal-free toxicity tests.

The Johns Hopkins animal alternatives center came into being, in large part, as a result of pressure from animal-welfare groups and individuals who deplored

C&EN staff photo

Animal-rights activist Spira (right) is crusading against the LD$_{50}$ test. A statistical model of the LD$_{50}$ developed by Enslein (far right) of Health Designs is reducing the need for the live-animal test

large-scale animal use in the Draize test. Once they were satisfied that positive steps were being taken to reduce the cosmetic industry's reliance on rabbits, animal advocates swiveled their guns on yet another toxicity test they saw as an outrage: the LD$_{50}$. The controversy surrounding this test quickly enveloped the scientific and regulatory communities.

The LD$_{50}$ (for Lethal Dose-50%) is designed to determine the single dose of a test chemical that will kill 50% of the animals under study. It involves giving several groups of animals, usually rodents, different dosages of the chemical and counting how many die within a given time period. Statistical methods are used to convert this body count into an LD$_{50}$ value.

This method has been used to evaluate the acute toxicity of a diverse range of substances, including cosmetics, detergents, pesticides, food additives, drugs, and other household and industrial products.

Toxicologists have found this test useful to gauge the relative acute toxicities of different chemicals and to set appropriate dosages for longer-term animal studies. And consumer-products companies have used it to assess how safe their products are. They explain that they need to know what a particular product will do if, for example, a child accidentally ingests it or spills it on the skin. They are obligated on moral grounds to do this, they insist.

But they are also bound by a legal obligation: Federal agencies such as the Food & Drug Administration, the Environmental Protection Agency, the Consumer Product Safety Commission, and the departments of Transportation, Agriculture, and Energy require that companies determine the acute toxic effects of their products. Some regulations, such as DOT's and EPA's, stipulate the LD$_{50}$ as a requirement. But other regulations merely "recommend" the LD$_{50}$ as a means of satisfying the requirement for acute toxicity data. In the past, many testing organizations have chosen, either because of convenience or misunderstanding, to comply with unspecific regulations by obtaining the required data using the universally accepted LD$_{50}$ test.

But a growing number of scientists now believe that the classic LD$_{50}$ test, developed in 1927, is "an anachronism," in the words of David P. Rall, director of the National Toxicology Program.

Activist Spira, who's led the assault on the LD$_{50}$, calls the test "a wasteful ritual exercise in misleading, meaningless precision." The test consumes a staggering number of animals each year, yet the numerical index of toxicity derived from it "is not terribly meaningful," echoes Goldberg of Johns Hopkins.

According to toxicologist Gerhard Zbinden of the Swiss Federal Institute of Technology, the LD$_{50}$ value for any compound is not a biologic constant and its determination is subject to enormous variability from laboratory to laboratory. In fact, he and many other scientists believe that a highly precise LD$_{50}$ determination is rarely necessary. The classical test typically uses 40 to 200 animals at one time. Yet the same information, he says, could be gleaned using fewer than a dozen animals.

The regulatory agencies have attracted much of the anti-LD$_{50}$ fire. "A simple change in regulatory requirements could, almost overnight, reduce animal use in the LD$_{50}$ test by 4.5 million animals—a 90% reduction," Spira asserts. "The real villain is the inertia inherent in any large bureaucracy. To overcome this inertia . . . requires enormous public pressure."

In his drive to build "a fire of public opinion under the regulatory agencies," Spira is getting support from several industry organizations. The Pharmaceutical Manufacturers Association, for example, has called for regulators to phase out the LD$_{50}$. It also has urged its member companies to use alternatives to the test. CTFA's board of directors also has joined the hue and cry and encouraged cosmetic companies to limit their use of the LD$_{50}$ whenever it's not essential.

Some federal bureaus and toxicology programs no longer use, or require the use of, the classic LD$_{50}$ test. But animal activists are pushing strongly for a total abolition of the test.

In response to this rising tide of opposition, FDA has scheduled a symposium on Nov. 9 that will examine regulatory requirements for the LD_{50}. The basic reason for the meeting, explains coordinator Phillip A. Johns, is to clarify for the public what the federal agencies' toxicity testing requirements really are. Johns, a toxicologist with FDA's Office of Science Coordination, says the public's confusion is mirrored by the animal advocates' newspaper ads implying that FDA is requiring "poor little dogs to be killed" in LD_{50} studies. In fact, he states, "we have not required or even suggested that anybody use dogs in an LD_{50} study for at least 35 years. It's almost a defamation of our agency."

According to industry sources, use of the classic LD_{50} test is reduced significantly already. Several modifications of the test that use far fewer animals have become ensconced in corporate testing labs. At Procter & Gamble, for instance, biostatistician Robert D. Bruce has developed an "up-and-down" method to pinpoint a chemical's acute toxicity. In this test, animals are dosed one at a time. If an animal survives for one or two days, the dose for the next animal is upped; if it dies, the dose is lowered. A computer program converts the data into an estimated LD_{50}. P&G says this procedure usually requires only six to 10 animals and gives results that are in "excellent agreement" with the standard test.

In certain cases, computer-generated mathematical models can estimate the LD_{50} of a new compound from its chemical structure and properties. According to Kurt Enslein, who heads a company called Health Designs in Rochester, N.Y., such predictive models can provide reasonably good LD_{50} estimates for about 80% of the compounds he has looked at.

To fashion Enslein's model for the rat oral LD_{50}, for example, a computer was used to pore over data from more than 6000 compounds. Using statistical methods, it culled the particular structural features and physical and chemical properties of the molecules that seemed to be most important in influencing their LD_{50}s, which were obtained from published studies. By plugging this same type of data for a new molecule into the equation, one can arrive at an estimate of the compound's oral LD_{50} in rats.

Enslein now has received support from an animal welfare group to refine this mathematical model so that it could be accepted by DOT as a substitute for the LD_{50} test. If his LD_{50} model is put into use, Enslein predicts, more than half of the compounds submitted for DOT approval will not need to be tested in animals.

Although recent public outcry has focused on the Draize and LD_{50} tests, scientists have been working successfully for years to reduce animal use in the testing of chemicals' long-term toxicity. Such chronic effects are insidious, often not surfacing until years or decades after the original exposure. For example, chemicals can cause chromosomal mutations that may appear as cancer or genetic diseases. Chemicals also can give rise to birth defects, cardiovascular disorders, and nervous system and behavioral problems.

Probing a new substance for mutagenic, carcinogenic, and teratogenic effects, until fairly recently could involve using hundreds, even thousands, of rodents. A lifetime study (18 to 24 months) of a chemical in one species of animal could cost $300,000 or more, says biologist Roland M. Nardone of Catholic University of America, Washington, D.C.

But in vitro methods using bacteria, cell and tissue cultures, fruit flies, and similar biological systems increasingly are allowing toxicologists to screen out "bad actors" at an early stage without resorting to live animals. At Procter & Gamble, for instance, a first-level mutagenicity screening consists of a battery of tests including the Ames bacterial assay, a mouse lymphoma assay, and other in vitro tests using hamster ovary cells and rat liver cells in culture.

Even neurotoxic effects can be tracked down without using live animals. At Catholic University, Nardone is developing an in vitro battery of tests to detect potential neurotoxicity of chemicals.

But in the realms of drug development and biomedical and behavioral research—where about two thirds of all lab animals are used—the outlook for replacing animals is dim. Donald G. Stein, director of the brain research laboratory at Clark University, Worcester, Mass., says it is "naive reductionism" to think that the behavior of a complex, living organism can be generalized from a layer of cells in a petri dish. Stein, who is using mice and rats to learn how to promote recovery from brain injury in humans, says that live animals are essential in his research, and will continue to be in the foreseeable future.

Many animal welfare groups, however, adamantly reject such views. For example, Aaron Medlock, executive director of the New England Anti-Vivisection Society, says that alternatives to animal experimentation could be found if scientists only tried hard enough.

The controversy enveloping the use of live animals in testing and research perennially surfaces on Capitol Hill. In the 98th Congress, two major bills address the issue. One proposal, sponsored by Sen. Robert Dole (R.-Kan.), would amend the Animal Welfare Act. His bill, designated S. 657, would provide researchers better access to information on improved methods of animal experimentation, including ways to reduce or replace animal use.

Dole's proposal, which is still in committee, also contains controversial provisions that some fear might lead to federal intrusion into the lab. Sen. Orrin G. Hatch (R.-Utah) terms the Dole bill "disastrous" and has introduced his own, S. 773. The Hatch bill calls for a comprehensive assessment of the current status of the use of live animals in biomedical and behavioral research. It is awaiting action on the Senate floor.

According to Hatch, it's unclear which alternatives to the use of animals should be promoted. This week, at his request, the Office of Technology Assessment is beginning an 18-month study to examine this question and other issues regarding animal experimentation and testing. The OTA study is expected to provide Congress with information necessary to consider further legislation in this area. And further legislation undoubtedly will be required, for no one expects animal testing, and the controversy surrounding it, to disappear any time soon. □